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The Relevance of Training for the Maintenance of Advanced Avionics

Polly Carpenter-Huffman and Bernard Rostker

A Project AIR FORCE report
prepared for the
United States Air Force

Rand
SANTA MONICA, CA. 90406

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This report is

An examination of formal training of airmen in the career fields responsible for flight-line maintenance of advanced avionics equipment. Initial training for flight-line maintenance, training at Field Training Detachments, TAC's Task Oriented Training program, and the management of training are investigated. The study shows that in initial training there was too much emphasis on theory and not enough on the practical knowledge and skills needed on the job. There was too little training on systems integration and troubleshooting integrated systems. To better prepare technicians for advanced avionics maintenance, formal training should teach job performance (rather than theory), should take place at the base and on the equipment the airman will be associated with, and should be interspersed with actual job experience. Training should be tailored to the needs of school personnel on training development and field evaluation of training should be lessened by having the users of trained personnel become active partners in the management of training. See also R-2017-AF and R-2049-AF. (JDD)

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PREFACE

This is part of a study requested by the Tactical Air Command because of problems arising from the support of advanced avionics systems. The material presented here in response, while highlighting the training of technicians who work on integrated avionics systems on the flight line, in fact has broad implications for Air Force technical training in general. It was provided to the Air Force in draft form and was widely briefed in the fall of 1975. The major audiences were Rand's Air Force Advisory Group; various planners in the Air Staff; the Commander, Air Training Command; and the Vice Commander, TAC.

In January 1976, the Chief of Staff of the Air Force established an ad hoc group to look for ways to cut the cost of training. This action was concurrent with ATC's reduction of basic electronics training and revision of the training given aircraft crew chiefs to make it specific to the job. These efforts led the ATC Commander in April 1976 to establish a major study effort, Hasty Grad, to review training policy and if necessary to revise it to ensure the relevance of technical training. Rand is a member of the Hasty Grad group.

The reader should therefore keep in mind the possible outcomes of the Hasty Grad deliberations. Our study raises serious doubts about Air Force training policy and, as noted, has major implications for the manpower, personnel, and training systems. Accordingly, one of the basic purposes of the Hasty Grad group is to evaluate these and related recommendations in an attempt to ensure the relevance and efficiency of technical training.

This report is one of a series examining personnel and training support for advanced avionics systems. Others are:

R-2017-AF, Analysis of the Content of Advanced Avionics Maintenance Jobs, Polly Carpenter-Huffman, John Neufer, and Bernard Rostker.

R-2049-AF, A Proposed Course for Avionics Technicians, Richard E. Duren.

The research was conducted for Project AIR FORCE (formerly Project RAND) under the study project "Personnel and Training Support for New Avionics Systems."

SUMMARY

The study from which this report emanated was requested by the Tactical Air Command because of problems arising from the support of the avionics systems in the F-111D aircraft. TAC, recognizing the complex nature of the problems, emphasized examination of Air Force management and training of maintenance personnel as well as hardware and software reliability. This report examines formal training of personnel for flight-line maintenance of all models of the F-111, concentrating on the bomb/nav systems in the F-111D.

One of the overriding impressions we received during extensive visits to all CONUS F-111 and F-15 bases and to the F-16 System Project Office is the pervasiveness of the personnel support problem. Although TAC highlighted the F-111D, we found the same problems in varying degrees with all integrated avionics systems. The integrated avionics system of the F-111D is at the frontier of technology and is the most difficult to maintain. Hence, deficiencies in personnel support are most obvious for this aircraft. Thus, while concentrating on the F-111D, our findings and recommendations have more general application.

Integrated avionics systems are distinctly different from earlier systems, although they perform the same functions of navigation, flight control, communications, and weapon control. In earlier systems, each function was carried out by separate pieces of equipment. In integrated systems, sensors and displays are tied together in a central computer complex via analog/digital converters.

Maintenance of earlier avionics systems focused on the separate pieces of equipment, and personnel in the same career field could work on the equipment for which they were responsible either on the flight line or in the intermediate shop. But integrated avionics systems are composed of sealed boxes; faulty boxes are identified through the use of self-test equipment on board the aircraft. The flight-line technician's responsibility is to remove and replace faulty boxes, which are then tested on special test stations in the intermediate shop. The shop technician's responsibility is to operate the test stations. The very different nature of flight-line and shop procedures led the Air Force eventually to assign flight-line and shop technicians to separate career fields.

Use of the built-in fault-isolation capability would make the flight-line job routine if the system provided unambiguous indications of failure. Such is not the case, not only because indicators are unreliable but because malfunctions may occur in several systems at once. Moreover, a malfunction in one system often affects the performance of a totally different system.

To evaluate training, we first had to establish the content of the flight-line maintenance job in terms of the skills and knowledge it requires. Because maintenance of the F-111 departs so radically from maintenance of earlier avionics systems, we undertook a unique data collection effort to establish the content of the job. We found that existing data collection systems, i.e., Occupational Survey and "66-1" maintenance activity reports, either did not cover flight-line avionics maintenance or did not capture the implications of task

performance for training. We therefore developed an "observation interview" procedure at Nellis and Mountain Home Air Force Bases and applied it at Cannon Air Force Base, where the F-111D is stationed. In order not to disturb normal work patterns and to maximize the number of cases an interviewer could efficiently handle, we debriefed maintenance teams immediately as they came off a job. During the first two weeks of April 1975, we were able to flow chart 188 jobs. Comparison of the jobs with Base Level Information System records shows that our sample was not unrepresentative of normal work patterns.

Our analysis showed that the most demanding part of the job--finding the bad box when self-test fails to do so--requires the informed use of combinations of the external indicators provided by the system; this, in turn, requires that the airman know how the system is integrated, what functions are performed in what boxes, and how a failure in a particular box affects the system. Furthermore, the avionics systems on each model of the F-111 are integrated so differently that knowledge of one does not presuppose knowledge of another.

With the above as background, we examined the way airmen have been and are being trained for flight-line maintenance. Although we concentrated on formal training for the critical Bomb/Nav shop (Air Force Specialty 326X2A), we also examined the other avionics flight-line specialties and TAC's Task Oriented Training (TOT) program. Even before we began our study, there were strong indications that something was wrong. The original training program stressed "representative" instruction, i.e., training on an item of

equipment that was thought to be similar to or representative of one or more other pieces of equipment. The system used was the FB-111, which has some systems found on no other model of the F-111 and lacks some systems that play key roles in other models. In 1974, the Avionics Superintendent Steering Group "concluded that the present representative training is not meeting the demands of the users...." They recommended "that representative training be replaced with weapons system oriented training." What was not generally understood was that training on specific avionics systems is necessary but not sufficient to ensure that the training is relevant to job performance.

An equally important problem was that most of the existing curriculum was theoretical and did not provide the technician with the practical knowledge or skills needed on the job. For example, 30 percent of the course dealt with basic electronics and 49 percent with systems familiarization. Instruction in actual job performance was limited to 11 percent of the course, with only half of that being hands-on instruction.

The inadequacy of this course was verified in several ways. As part of the debrief interviews at Cannon, we asked each technician about the source of training he had received for each step of the task. In the Bomb/Nav shop, the technical school course was mentioned as the source of knowledge in only 5.5 percent of the responses. In early 1974, TAC administered a questionnaire on the adequacy of training (among other subjects) to a large number of Specialty Code 326 personnel stationed in the CONUS and overseas.

Although the questionnaire did not permit statistical analysis of responses, the tone of the responses was clear. Training in basic electronics was irrelevant to the job, there was too much theory and not enough practical training, and there was too little training on systems integration and on troubleshooting integrated systems. Moreover, in the spring of 1974, after trips to Nellis and Mountain Home Air Force Bases, an Air Training Command (ATC) evaluation team noted similar complaints and concluded that "most graduates interviewed considered the Lowry [Technical School] course inadequate for doing their job."

The use of the FB-111 as a training vehicle and the emphasis of the course on abstract knowledge were partly consequences of Air Force training policy. Traditionally, initial training has been designed to provide a base for an airman's performance of various duties as he progresses in his specialty and as he works on the various weapon systems assigned to it. Such training has stressed general knowledge related to the career field rather than the specific job. This is presumed to facilitate flexible assignment of personnel among bases and weapon systems. In the case of integrated avionics, however, the desired transfer of learning was not taking place because of the irrelevance of the general principles taught and the idiosyncratic nature of advanced avionics systems.

The need for training in practical knowledge and skills was clearly understood at Cannon Air Force Base. The 27th Tactical Fighter Wing extended the principles of job performance training embodied in the experimental Task Oriented Training program to the training of Bomb/Nav technicians. Although this program was limited

to Bomb/Nav personnel, its high degree of acceptance demonstrated the feasibility and potential value of job performance training.

In the meantime, because of concern about the effectiveness of representative training, ATC developed a new two-phased training plan for the Bomb/Nav division of the career field. Phase I included basic electronics and other material common to training for all Bomb/Nav personnel and was taught at Lowry Technical School. Phase II was conducted at five CONUS Field Training Detachments (FTDs), one for each model of the F-111 and for the F-15.

Although we have not had sufficient experience with the revised course to evaluate its graduates, we have examined its basic content in detail. First, without specific reference to the needs of the job, it substantially expanded basic electronics to 40 percent of the course. Our analysis indicated that most of this training does not add to the effectiveness of flight-line maintenance. This conclusion is supported by a review of the General Dynamics Fault Isolation Verification Program data and an independent evaluation by a member of Rand's engineering staff (see R-2049-AF).

Second, as noted, weapon system training is not sufficient to ensure job performance training. In order to better understand Phase II, we visited Nellis, Plattsburg, and Cannon Air Force Bases. In general, Phase II instruction was developed without a detailed analysis of the job, without an approved Specialty Training Standard (STS), without involvement of wing personnel, and without taking full advantage of the on-base location to ensure the relevance of the hands-on portion of training. The planned courses were combinations of the previous technical school and FTD courses.

Putting together our understanding of the job, the existing training program, and previous research by Rand and others, we recommend that training be developed for flight-line maintenance of advanced avionics that stresses five principles:

1. Job Performance Should Be Taught. Almost all of the skills and knowledge necessary to do the job must be learned because they are not part of the average person's repertoire. Most cannot be learned or derived from fundamental principles. Moreover, the performance of tasks that are idiosyncratic to specific systems should be taught on the actual systems or adequate facsimiles of them.

2. Only Job Performance Should Be Taught. Career orientation of entry-level training for integrated avionics is inefficient because only a small percent of the graduates of the initial course make the Air Force a career. Our analysis of Uniform Airman Records indicated that on the flight line only 13.9 percent of technical school graduates stay until their fifth year of service.

3. Job Performance Should Be Taught Formally. Currently, the Air Force expects most job skills to be taught informally through on the job training (OJT). However, recent studies of the Human Resources Research Office at George Washington University and the Air Force Human Resources Laboratory indicate that formal training of job skills is more effective. Formal training provides a controlled environment that ensures that all of the important tasks will be taught, that each trainee will be taught the tasks, and that he will learn to do the tasks correctly. Teaching job performance in formal

training produces an airman who is of immediate use to the operating unit and reduces the substantial hidden cost of OJT.

4. Job Performance Should Be Taught Formally at the Operating Base and When Needed. Teaching job performance at the operating base improves access to the job itself, which, if taken full advantage of, would significantly improve the relevance of training. For example, at Cannon Air Force Base, Task Oriented Training instructors were taken from TAC units on base. The instructors were able to maintain better contact with the job, the idiosyncrasies of the equipment, and the needs of the shops. Moreover, base-level training would be readily available to instruct the technician as he moves between jobs in his specialty or is reassigned to bases that have different pieces of equipment.

5. Initial Formal Training Should Be Alternated with Job Experience. Because of the complexity of the equipment and the job, alternating periods of formal training with actual job experience would have several advantages. It would shorten the initial period of training and enable the airman to perform simple tasks while they are still fresh in his mind. Actual job experience would provide a frame of reference and motivate him to the more intellectually demanding tasks of troubleshooting. In short, training and the job would reinforce each other.

During our inquiry into avionics training, we had an opportunity to observe the management of training first hand. During periods of rapid change, it is all too easy for close ties between training and the job to be broken. The management procedures devised by the Air

Training Command to ensure that training is responsive to the needs of the field sometimes are ineffective. Though they seem straightforward, they ultimately rely largely on subjective judgment for detailed specification and implementation. This judgment is generally supplied by a relatively small group of people, the subject matter specialists at the technical schools, and their perceptions are naturally colored by the school environment.

Although there are many points at which other Air Force agencies, and other echelons of ATC itself, can participate, both formally and informally, in the management of training, this participation is seldom aggressive. This became clear as we traced in detail the management of Bomb/Nav avionics maintenance training. For example, the Specialty Training Standard is written by ATC's subject matter specialists and approved by the commands that use the trained personnel. The STS is crucial because it is the document from which the course is to be derived. We found, however, that TAC's approval of the STS was perfunctory. In fact, TAC had approved an STS that required TAC technicians to be tested for promotion on SAC equipment (the FB-111), which was very unlike the equipment they had been working on.

We found similar inconsistencies in the evaluation of training. One major problem is that ATC asks the other commands to evaluate graduates on the basis of ATC criteria rather than on those of the commands. Moreover, the criteria are ambiguous. Thus, an ATC trip report concluded that "not enough performance training is given in tech school" and "most graduates interviewed consider the Lowry

course inadequate for doing their job," while a formal ATC review concluded that

> all STS items were being taught to the code level given in the training standard ... internal review of the course did not indicate any training deficiencies other than down time of training equipment.... Personnel interviewed ... seemed to indicate that the graduates were not fully trained on all models.... This is a normal condition where the graduates may be assigned to more than one model aircraft. Recommend ... (purchase of) selected additional trainers.

Our study highlights three areas in which the management of training can be improved. First, strengthen the formal procedures referred to as Instructional System Development by improving techniques for task analysis and field evaluation. Second, provide flexibility by changing the blanket policy that initial training should prepare airmen for career advancement to one that permits training to be tailored to the needs of each specialty. Third, ensure that the users of trained personnel are active partners in training management.

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I. INTRODUCTION

THE PROBLEM

Aircraft with integrated avionics systems began entering Air Force operating units with the F-111A in 1968. Since then, avionics packages have become increasingly sophisticated and complex, culminating with the Mark II package on the F-111D. Unfortunately, as sophistication increased, both reliability and the ability of Air Force personnel to maintain the systems decreased. In 1973, there was an average of two flying hours between component removals for the total Mark II package. Moreover, about 28 percent of the removed components later tested OK on the automatic test equipment.* Such frequent removals generated heavy loads on maintenance personnel and reduced rates of operational readiness to unacceptable values.

ORIGIN OF THE STUDY

This study was initiated at the request of the Tactical Air Command (TAC) for a "disinterested agency" study of problems with the support of the Mark II system in the F-111D. TAC, recognizing the complex nature of the Mark II problem, emphasized examination of personnel and training support. In characterizing previous efforts, TAC set the tone for the present study: "to date, these multiple problems have essentially been addressed individually, as separate

*F-111D Mark II Fault Isolation Verification Program (FIVP), Progress Report No. 2, General Dynamics Corporation, Convair Aerospace Division, Fort Worth, Texas, FZM-12-8301, April 8, 1974, p. 14.

entities, with little in-depth consideration of the complex interrelationships which exist between them."*

Initial Rand efforts to identify the causes of support problems associated with the Mark II in the F-111D began with orientation visits to the following Air Force organizations: Headquarters, Tactical Air Command; the Air Training Command's Lowry Technical Training Center (which is responsible for training many of the personnel who maintain the F-111D); the Military Personnel Center; the Air Staff (DPXOS, DPPT, and LGYY); the 366th Tactical Fighter Wing, Mountain Home Air Force Base, Idaho (F-111F); and the 27th Tactical Fighter Wing, Cannon Air Force Base, New Mexico (F-111D).** Visits to the operational bases concentrated on the Avionics Maintenance Squadrons (AMSs) and Field Training Detachments (FTDs).

SCOPE OF THE STUDY

One of the overriding impressions received during these visits to Air Force installations was the broad nature of the support problem. TAC had indicated its concern about the Mark II in the F-111D, but we found that the problem was endemic to current integrated avionics systems, to the maintenance concept as applied, and to the current structure of the integrated maintenance career field (AFS 326). Therefore, we could expect similar problems in varying

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*Letter and attachment from Col. V. R. Hollandsworth, Director of Maintenance Engineering, Headquarters, Tactical Air Command, November 5, 1973.

**Subsequently, project staff have visited Edwards (F-15), Langley (F-15), Nellis (F-111A), and Plattsburg (FB-111A) Air Force Bases and the Miramar Naval Air Station (F-14), as well as the F-16 Special Projects Office.

degrees in other aircraft using integrated avionics systems. In the present inventory, this includes all models of the F-111 (F/FB-111A,D,F,E), the A-7D, the C-130E, the C-5A, and the F-15. In the future, similar problems are likely to be seen on the F-16. Air Force experience with the first F-15 operational unit has reinforced our belief that the problem is more general than first thought.

Our research indicates that there are serious problems in six interrelated areas: the structure of the integrated avionics career field; the manpower system, which establishes requirements for maintenance personnel; the personnel assignment/management process, which, working with gross manpower requirements, translates authorizations into trained and experienced personnel; the "what, where, and how" of formal, on the job, and FTD training; the logistics support, which provides the technical environment in which trained and experienced personnel maintain avionics systems; and, of course, the reliability of the hardware and software that make up advanced avionics systems.

PLAN OF THE REPORT

This report concentrates on formal training for flight-line maintenance. Following the introduction, the nature of integrated avionics systems and the career field and training structures that support their maintenance on the flight line are described in Sec. II. The critical first step in evaluating the training program is to establish the content of the job in terms of the skill and knowledge required; this is described in Sec. III. Section IV contains a detailed analysis of the current training program, highlighting

entry-level training, current plans for revision of that training, and the Task Oriented Training program that TAC established at Cannon Air Force Base. Next, Sec. V explores an alternative to the current training system based upon the unique nature of avionics maintenance, the observed shortcomings of the current system, and previous research on effective technical training systems. The need for improvements in procedures for designing and evaluating training programs is discussed in Sec. VI. The concluding section gives recommendations for training content and management.

II. BACKGROUND

THE INTEGRATED AVIONICS MAINTENANCE CONCEPT

The Mark II is the prime example of an integrated avionics system. It is distinctly different from earlier systems, although it performs the same functions of navigation, flight control, communications, and weapon control. In earlier systems, these functions were carried out by separate pieces of equipment, each with its own sensors, computational devices, and displays. The first and simplest form of integration combined all computational requirements in a single executive computer. With the advent of powerful digital computers, the next step was to provide separate analog/digital converters for each sensor. The Mark II, containing a central data converter and computer complex, is at the frontier of current technology.*

Maintenance of earlier avionics systems focused on the separate pieces of equipment. Technicians worked on the flight line where they could test avionics equipment on the aircraft and perform minor adjustments and repairs. If they discovered equipment needing major repair, it was sent to the intermediate shop where it was bench-checked on a "hot mockup," an operating version of the full avionics system. Equipment that could not be repaired in the shop was sent to a depot for repair or disposal. Personnel in the same career field could work either on the flight line or in the shop, although

*See Harry I. Davis, "Military Avionics--How Much Integration?" Astronautics and Aeronautics, Vol. 5, No. 6, June 1967, p. 53.

flight-line technicians tended to consider a move into the shop a promotion because of its greater demands for technical competence and its better working conditions.

Integrated avionics systems are similarly supported by the Air Force's three levels of maintenance--flight line (or organizational), intermediate shop, and depot.* To facilitate rapid turnaround, advanced complex avionics systems are designed with on-board test equipment that was originally expected to identify malfunctioning components 95 percent of the time without the use of external flight-line AGE (Aerospace Ground Equipment) test sets.** In addition, avionics circuitry is housed in sealed containers, termed Line Replaceable Units (LRUs), which cannot be opened on the flight line. Sometimes referred to as "black boxes" (although they are more often gray), LRUs can easily be removed from the aircraft and replaced with a workable spare.

Repair of the LRU is the job of the intermediate maintenance shop. Using test stations that are controlled either manually or by computer, the circuitry of each LRU is tested independently against predetermined tolerance limits, a very different process from the hot mockup used in earlier avionics systems. Test stations are designed

*See System Specification for Air Combat Fighter Systems 2185 (F-16A and F-16B), General Dynamics Corporation, Fort Worth, Texas, December 16, 1974.

**AFR 375-11 defines on-board test equipment as "An avionics subsystem designed to monitor, analyze, isolate, display and record faults in aircraft subsystem performance. This system can display substandard performance and malfunction data on board the aircraft and during flight, as well as for the guidance of the maintenance technician on the ground." Also see Carl B. Nichols, Jr., Improving Reliability and Maintainability in Avionics, Professional Report No. 4669, The Air War College, The Air University, Maxwell Air Force Base, Alabama, April 1972, p. 23.

only to identify malfunctioning subcomponents or Shop Replaceable Units (SRUs), usually a circuit board. Intermediate shop technicians repair LRUs by removing and replacing faulty SRUs. Malfunctioning SRUs are generally sent to a depot to be repaired or thrown away.

In sum, maintenance of advanced avionics systems is designed to be accomplished through three levels. Avionics systems are composed of individual LRUs; faulty LRUs are identified through the use of on-board, integrated test equipment, generally without the aid of external flight-line AGE. Removed LRUs are tested in the intermediate shop on test stations that check internal circuitry against predetermined tolerances. Shop action is limited to the removal and replacement of SRUs, whose repair is the responsibility of the depot.

THE OCCUPATIONAL CONCEPT--THE 326 CAREER FIELD

To support the new maintenance concepts of the F-111, the Air Force put flight-line and shop personnel in separate career fields.* During the period of this study, these career fields had the structure shown in Table 1, although the structure has been changing since the advent of integrated avionics systems. A brief description of these changes reveals the fluidity of the situation.

Originally flight-line and shop personnel were separated by designating the traditional avionics and communication-electronics Air Force Specialty Codes (AFSCs) with a "V" prefix for shop maintenance and a "U" for flight-line maintenance. In 1968, the Air Force

*AFM 66-1, Vol. V, puts these responsibilities in separate shops in the F-111 Avionics Maintenance Squadrons.

Table 1

STRUCTURE OF INTEGRATED AVIONICS MAINTENANCE CAREER FIELDS, 1975

(a)
Integrated Avionics Systems Specialists/Technicians
(Flight-Line Maintenance Only)

Equipment	Specialty
Weapons control/inertial navigation ("Bomb/Nav")	AFS 326X2A
Automatic flight control/instruments ("Instrument/Autopilot")	AFS 326X2B
Communications/navigation/penetration aids ("Comm/ECM")	AFS 326X2C

(b)
Integrated Avionics Component Specialists/Technicians
(Intermediate Shop Maintenance Only)

Equipment and Function	Specialty
Automatic test station operator	AFS 326X1A
Manual test station operator	AFS 326X1B
Aerospace ground equipment repairman	AFS 326X0

established a new AFSC to troubleshoot, repair, and calibrate all F-111 Category II AGE, including test stations. Selected personnel from each "V" prefixed AFSC received conversion training, became Avionics Aerospace Ground Equipment Specialists/Technicians, and were awarded a 326X0 AFSC. In 1970, a further conversion consolidated the "V" prefixed AFSCs. After conversion training, airmen were reclassified as Integrated Avionics Component Specialists/Technicians and awarded either a 326X1A or 326X1B AFSC. The A "shred"* was responsible for testing navigation/flight and weapon control and flight data recorder systems (usually on computer-controlled or "automatic" test stations.) The B shred was responsible for testing communication/mission, traffic control, and penetration aids on "manual" test stations. While not responsible for the maintenance of the test station, the "X1s" are responsible for its operation. Their major functions are the test, troubleshooting, repair, and alignment of LRUs.** In 1975, a further shred realigned the shop AFSCs.

The consolidation of shop AFSCs prompted similar action for the flight line two years later. In January 1972, the flight-line AFSCs were realigned as 326X2A,B,C--Integrated Avionics Systems Specialists/Technicians. The A shred is responsible for bombing, navigation, and fire control systems, digital computers, and multi-sensor displays. The B shred is responsible for flight control and integrated/mechanical instruments. The C shred is responsible for communication, navigation, and electronic countermeasure systems.

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*A "shred" is a division of a career field; it is indicated by a letter suffix.

**See AFM 39-1, Airman Classification Manual.

The range of responsibility of the 326 career field is shown in Table 2. Technicians in AFSC 326 are responsible for a large number of systems; furthermore, the systems are housed in a large number of aircraft types. The range will be substantially increased when the F-16 and B-1 join the active inventory.

CAREER PROGRESSION

Progression in AFSC career field 326 is consistent with the general Air Force pattern. An airman progresses in a dual skill level and grade system within his AFSC. The key to progression in both tracks is the Specialty Training Standard (STS). Air Force Regulation 8-13 notes, "An STS outlines the training required to achieve a skill level(s) within an Air Force Specialty (AFS). Through its use, the individual training of airmen is standardized and the quality of training controlled."

In general, an airman in any of the six 326 AFSCs progresses from the "1" or helper level, to the "3" or apprentice level, through the "5" or specialist level, to the "7" or technician level, without leaving the AFSC. The six 326 AFSCs funnel into a common "9" or superintendent level. Thus a man in a 326 flight-line shop looks forward to a career on the flight line, unlike his counterparts who work on less advanced avionics. Other avionics AFSs (such as 322X1Q for the F-4E) encompass both organizational and intermediate level maintenance, and there is appreciable circulation of personnel between the two levels both as they perform day-to-day maintenance tasks and as they progress in their careers.

Table 2

AFSC 326 CAREER FIELD RESPONSIBILITIES

326X0 - Avionics AGE Technician	326X1A - Avionics AGE Operator	326X1B - Avionics AGE Operator
Duties: Repairs, calibrates, maintains, and troubleshoots avionics AGE for: All AF Cat II AGE All A-7 Test Stations (9) AC-130 Test Station (1) All C-5 Test Stations (6) All F-15 Test Stations (7) All F/FB/EF-111 Test Stations (31)	Duties: Operates all Test Stations (automatic or manual) to verify, repair, or troubleshoot system LRUs for: F/FB/EF-111 - WCS ARS (-113/114/144/130) INS TFR LARA DCC Converter AFCS Bomb/Nav FB-111 - Astrotracker F-111D - IDS FB-111 and F-111D - HSD F-15 - Same systems as listed above	Duties: Operates all Test Stations (automatic or manual) to verify, repair, or troubleshoot system LRUs for: F/FB/EF-111 - Comm/Nav ILS IFF TACAN CADC Electrical Pen Aids (ALQ-94) RHAW (APS-109/ALR-41) Infrared (AAR-34) F-111D/FB-111 - Doppler F-15 - Same systems as listed above
Future responsibilities: All B-1 Test Stations (?) All F-16 Test Stations (?)	Future responsibilities: B-1 - Same systems as listed above F-16 - Same systems as listed above	Future responsibilities: B-1 - Same systems as listed above F-16 - Same systems as listed above
326X2A - Avionics Flight-Line Technician	326X2B - Avionics Flight-Line Technician	326X2C - Avionics Flight-Line Technician
Duties: Repairs, maintains, and troubleshoots the following aircraft systems: F/FB/EF-111 - WCS, ARS, INS, TFR, Bomb/Nav, Converter, DCC, IDS, LARA, Astrotracker, HSD, Doppler F-15 - Same systems as F-111	Duties: Repairs, maintains, and troubleshoots the following aircraft systems: F/FB/EF-111 - AFCS, Instruments, Fuel Quantity, CADC F-15 - Same systems as F-111	Duties: Repairs, maintains, and troubleshoots the following aircraft systems: F/FB/EF-111 - Comm/Nav, TACAN, ILS, Pen Aids, RHAW, IR F-15 - Same systems as F-111
Future responsibilities: B-1 - Same systems as F-111 F-16 - Same systems as F-111	Future responsibilities: B-1 - Same systems as F-111 F-16 - Same systems as F-111	Future responsibilities: B-1 - Same systems as F-111 F-16 - Some of the F-111 systems

Airmen are awarded their 3-level after they complete basic technical training. It is Air Force policy that 3-levels (and below) must work under direct supervision unless the specific task they are performing has been "signed off" in their STS. Similarly, at least a 7-skill level is required for an airman to be designated a production inspector.* Advancement to the 5-level requires demonstration of proficiency and knowledge of specific tasks, as specified in the STS. The STS also requires the completion of prerequisite Career Development Courses (CDCs) before skill advancement.

Grade promotion is also tied to skill advancement as set out in the STS. The Specialty Knowledge Test (SKT) is an important part (22 percent) of the Weighted Airman Promotion System. Questions on the test for promotion to E-5 are based on "5-skill level" knowledge as defined by the CDC and the STS. Promotions to E-6 and E-7 are based on "7-skill level" knowledge. The relation of the skill levels and grades is shown in Table 3. Progress in skill level always precedes (but does not automatically cause) progress in grade.

The STS establishes proficiency required at the 3-, 5-, and 7-skill levels in subject knowledge, task knowledge, and task performance. Table 4 shows the general proficiency level in each of the areas and for each skill level. The terms "task performance" and "task knowledge" obviously are keyed to a specific task, whereas the term "subject knowledge" refers to knowledge that is related to more than one task in the specialty or that provides a general understanding of the specialty.

*See AFM 66-1, Vol. 5, pp. 2-2 and 3-2.

Table 3

CRITERIA FOR PROMOTION

Grade	Criteria
E-2	Four months time in grade with satisfactory performance.
E-3	Eight months time in grade with satisfactory performance.
E-4	Eight months time in grade; one year time in service; satisfactory performance. In addition, the 5-skill level must have been obtained by the first day of the month preceding the month in which the promotion will be effective. Currently, the planned promotion "phase point" for E-4 is 31 months time in service. Promotions are awarded as vacancies occur.
E-5	Twelve months time in grade and three years time in service. Must have 5-skill level.
E-6	Eighteen months time in grade and five years time in service. Must have 7-skill level. Promotion is governed by the Weighted Airman Promotion System.
E-7	Twenty-four months time in grade and eight years time in service. Must have at least 7-skill level. Promotion governed by the Weighted Airman Promotion System.
E-8	Twenty-four months time in grade and 11 years time in service. Either 7- or 9-skill level. Must qualify under the USAF Supervisory Examination. Promotion determined by board.
E-9	Twenty-four months time in grade and 14 years time in service. Must have 9-skill level. Promotion determined by board.

Table 4

AVERAGE STS REQUIREMENTS

Skill Level	Area	Proficiency Level
3	Subject knowledge	Can explain relationships of basic facts and state principles. (Principles)
	Task knowledge	Can determine step-by-step procedures for doing task. (Procedures)
	Task performance	Can do most parts of the task. Needs help only on hardest parts. May not meet local demands for speed or accuracy. (Partially proficient)
5	Subject knowledge	Can analyze facts and principles and draw conclusions about the subject. (Analysis)
	Task knowledge	Can explain why and when the task must be done and why each step is needed. (Operating principles)
	Task performance	Can do all parts of the task. Needs only a spot-check of completed work. Meets minimum local demands for speed and accuracy. (Competent)
7	Subject knowledge[a]	Analysis
	Task knowledge[a]	Operating principles
	Task performance	Can do the complete task quickly and accurately. Can tell and show others how to do the task. (Highly proficient)

[a] The STS format provides for higher levels of proficiency in subject and task knowledge, but they are not required of 326 technicians.

TRAINING IN THE 326 CAREER FIELD

The interaction of the 326 AFS with its supporting training program is illustrated in Fig. 1. Training generally consists of formal classroom instruction at one of the Air Training Command's residential technical training centers and on the job training in an operational unit. After receiving basic military training, an airman assigned to the 326 AFS is sent to technical school for formal 3-level training. After graduation and assignment to an operational unit, he enters the OJT program. "On-the-job training is a planned training program designed to qualify airmen, through self-study and supervised instruction, to perform in a given Air Force Specialty (AFS) while actually working in a duty assignment of the AFS."* On the job training in the 326 AFS consists of basic knowledge instruction through the Career Development Course (a correspondence course), and proficiency training conducted by unit personnel. Field Training Detachment courses may augment the OJT program.

Basic Technical Training

After completing basic military training, an airman enters basic technical training at one of the technical centers of the Air Training Command. This training is often referred to as 3-level training because the airman is awarded his 3-level on successful completion. It usually consists of classroom and laboratory instruction and typically progresses from instruction in general theory to instruction relevant to specific equipment and to the development of skills in using or repairing that equipment.

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*See AFR 50-26 and AFM 50-23, Guide for Planning and Conducting On-the-Job Training, p. 1-1.

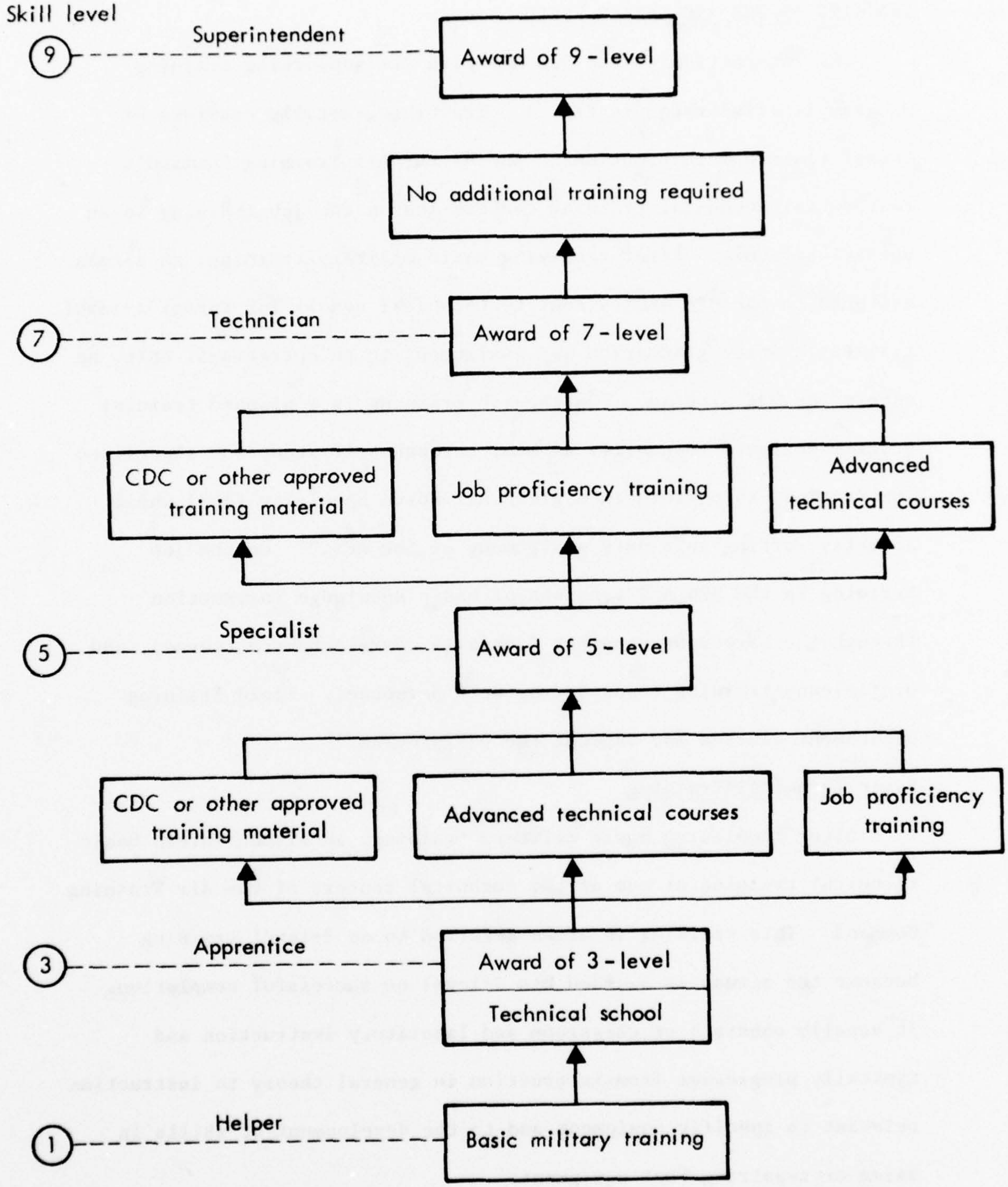

Fig. 1 — Relation between skill levels and training program

As Table 4 shows, typically the 3-level technical school graduate is supposed to be able to "do most parts of the task," as specified in the STS. He "needs help only on hardest parts," but "may not meet local demands for speed or accuracy." He should be able to "determine step-by-step procedures for doing the task" and "explain relationships of basic facts and state general principles about the subject."

The Air Force devotes more resources to 3-level training than to any other training it conducts. This training provides a screening function by eliminating men who cannot or will not acquire the technical knowledge needed for the job. It is often the only formal (and therefore controllable and observable) training a man receives; once a man is assigned to an operating command, it is often difficult to interrupt his productive time with further training. Thus, because the basic technical course so often provides the only structured opportunity a man has to obtain technical knowledge, ATC holds that the course must expose everyone in the career field to the full range of subjects they may need to know, wherever they may be assigned.

With the exception of training for AFSC 32632C, all 3-level technical training is conducted at one of the resident centers. As of the beginning of 1975, with the exception of the 326X2B and C fields, basic technical training in the 326XXX fields was conducted at Lowry Technical Training Center. The complete list of centers responsible for 326XXX courses is given in Table 5. The first part of training for the C shred, basic electronics and communications, is taught at Keesler Air Force Base. The second part is taught in the FTDs located at the various F/FB-111 operating bases. Students taking these courses are still assigned to the Air Training Command (as indicated

by their 2-level status), not to an Avionics Maintenance Squadron. After graduation from the FTD course, the new 32632C apprentice is assigned to an AMS at the same or another base.

Table 5

326 AFS TECHNICAL CENTERS

AFSC	Technical Center
32630[a]	Lowry AFB, Denver, Colorado
32631A[a]	Lowry AFB
32631B[a]	Lowry AFB
32632A[a]	Lowry AFB
32632B	Chanute AFB, Rantoul, Illinois
32622C	Keesler AFB, Biloxi, Mississippi
32632C	FTDs at Mountain Home, Cannon, Nellis, and Plattsburg AFBs

[a] Under revision as of first writing (November 1975).

As in other electronics specialties, technical training in the 326 AFS is divided into two parts. The first part consists of basic or fundamental electronics; and the second concerns the specific

systems that men in the career field are responsible for. Table 6 shows the major topics in the basic electronics course for each field before mid 1975. Airmen assigned to intermediate maintenance shops (X0, X1A, and X1B) take the same 300-hour (10-week) course. All basic electronics courses in the technical centers are taught by self-paced instruction (with recent exceptions, as discussed later).

After they have passed electronics fundamentals, airmen are trained in "set school" on equipment associated with their AFSC. Table 7 shows the former equipment-oriented training in the 326XXX AFSCs. Also shown in Table 7 are the particular models of F-111 to which the training was oriented. Training was not given on all models of the F-111 because ATC was unable to purchase all of the equipment found in the various F-111 models. For example, the F-111A and E models have no signal converter unit; the FB, D, and F models each have a different converter set; and there are four different terrain following radar (TFR) sets on the five F-111 models. To cope with this problem, ATC adopted a "representative training concept," that is, they made the equipment they had represent other equipment in the career field by emphasizing features that were similar on the various models. The Specialty Training Standard, and thus the Career Development Course and Specialty Knowledge Test, reflected the representative training concept by stressing systems and tasks specific to the equipment available at Lowry AFB and by referring to the technical orders associated with that equipment.

The deficiencies of representative training for 326X2A AFSC were evident almost from the outset. Action was taken in late 1974 to remedy these deficiencies after TAC had initiated a series of special

Table 6

COURSE HOURS FOR BASIC ELECTRONICS IN 326 AFS

Major Topics	Inter-mediate Shops	Flight-line		
		-32A	-32B	-32C
Orientation	2	2	4	3
Safety and First Aid	2	2	2	3
Structure of Matter	1.5	1.5	2	
Theory of Electron Flow	1	1		
Schematic Symbols	2	2	2	10
Power of Ten and Metric Conversion	4	4	4	
Soldering Techniques and Printed Circuit	2	--	--	--
Resistance and PSM 6 Ohm Meter	6	6	10	9
DC Ohm's Law and Power Law	8	8	7	
Series Circuits	5	5		
Parallel Circuits	6	6	26	10
Series/Parallel Circuits	6	6		
Voltage and Current Dividers	3.5	3.5	--	--
Bridge Circuits	4	--	2	--
Magnetism and DC Meters	4	4	3	3
Principles of Generation and Alternating Current	4.5	4.5	9	8
Capacitance	--	--	5	--
Vacuum Tube Voltmeter Operation	5	5	--	--
Oscilloscope Operation	6	6	--	6
Electromagnetism and Relays	4	4	--	--
Reactance and Reactive Circuits	9	9	--	--
Series and Parallel Impedance	10	--	--	--
Resonance	10.5	--	--	--
DC Motors	4	4	4	--
AC Motors	4	4	5	--
Vacuum Tubes and Tube Testing	--	6	--	--
Solid State Theory	11	7	6	--
Principles of Transistors	9	6	12	8
Transistor Testing	3.5	--	--	--
Four Layer Devices	5	--	--	--
Photosensitive Devices	3	--	--	--
Transformers	2	2	4	3
Transients and Time Constants	3	--	--	--
Integrators	2	--	--	--
Differentiators	2	--	--	--
Rectifiers	3.5	3.5	3	--
Filters	4	4	--	--
Voltage Doublers	3	--	--	--
Regulated Power Supplies and Zener Diodes	5	5	3	3
Silicon Controlled Rectifiers	2	--	--	--
Troubleshooting Fundamentals	3	--	--	--
Basic Amplifier Configuration	6	6	8	3
Audio Amplifier	7	--	--	--
Video Amplifier	4	4	--	--
Push-Pull Amplifiers	5	--	--	--

Table 6 (continued)

Major Topics	Inter-mediate Shops	Flight-line		
		-32A	-32B	-32C
Field Effect Transistors	3.5	--	4	--
Unijunction Transistors	3	--	--	--
Servo Control Systems	--	4	2	3
Basic Oscillator Principles	5	5	5	3
Limiters and Clampers	--	5	--	--
Complex Waveform Analysis	2	--	--	--
Solid State Switching	4.5	--	--	--
Multivibrators and Schmitt Triggers	7	7	7	--
Digital Mathematics	6	6	--	3
Digital Computers	--	1	--	--
Analog Computers	2	2	--	--
Logic Circuit and Truth Tables	4	4	--	6
Boolean Math	3	3	--	--
Introduction to Integrated Circuits	1	--	--	--
Adder Circuits	3	--	--	} 2
Counter Circuits	3	--	--	
Registers	3.5	--	--	--
Decoding Circuits	5	--	--	--
Operational Amplifiers	4	--	--	--
Digital to Analog Converters	4	--	--	--
Analog to Digital Converters	4	--	--	--
Timing Control Circuits	6	--	--	--
Programming Principles	4	--	--	--
Programming Applications	4.5	--	--	--
Storage Devices	6	--	--	--
Basic Transmitter and Receivers	--	--	--	24
Transmission Devices	--	--	--	17
Cable Fabrication and Troubleshooting	--	--	--	19
Intercommunication Systems	--	--	--	6
UHF/ADF Systems	--	--	--	8
HF Systems	--	--	--	6
ILS Systems	--	--	--	8
TACAN Systems	--	--	--	9
IFF/SIF Systems	--	--	--	9
Aircraft Wiring and Electronic Symbols	--	--	--	8
Measurement and Critique	15	4	6	12
Total	300	172	145	212

Table 7

RESIDENT TECHNICAL TRAINING IN THE 326 AFS

AFSC	Course Title	Effective Date	School	Length, hr	Aircraft Orientation (Representative Training)	Course Content (Systems Only)
32632A	Integrated Avionics Systems Specialist 3ABR32632A	3 December 1973	Lowry	387	FB-111	Introduction, 36 hr; INS, 39 hr; ODSS, CDS, and DCC, 54 hr; ARS, 66 hr; TFR, 48 hr; DRS and LARA, 36 hr; Systems Integration, 108 hr.
32632B	Integrated Avionics Systems Specialist	6 November 1974	Chanute	384	F-111A	Introduction, 60 hr; Engine Inst, 36 hr; Flight Inst, 30 hr; Integrated Flight and Nav. Inst, 54 hr; Integrated Flight Controls, 54 hr.
32632C	Integrated Avionics Systems Specialist (Comm, Nav, ECM) 4ABF32632C	15 October 1973	Sheppard and F-111 FTDs	300		Comm. Sys., 90 hr; Elec. Nav. Sys., 48 hr; RIS, 30 hr; RHWS, 60 hr; ECM, 72 hr.
32630	Avionics Aerospace Ground Equipment 3ABR32630	13 March 1974	Lowry	613	F-111D	Introduction, 30 hr; Manual Test Stations, 74 hr; Auto Test Stations, 92 hr; Maint. Auto Test Stations, 29 hr; GPC Operation, 60 hr; Interface, 35 hr; Video Test Stations, 132 hr; Maint. Video Test Stations, 42 hr; Pen Aids Test Stations, 86 hr; Maint. Pen Aids Test Stations, 33 hr.
32631A	Integrated Avionics Component Specialist	31 July 1974	Lowry	416	F-111D	Introduction, 54 hr; Video Test Stations, 62 hr; WDC Test Stations, 60 hr; CS-FC Test Stations, 44 hr; ES Test Stations, 36 hr; Radar Test Stations, 48 hr; S/I Test Stations, 44 hr; Display Test Stations, 47 hr; A&R Test Stations, 21 hr.
32631B	Integrated Avionics Component Specialist	31 July 1974	Lowry	463	F-111D	CADC, 50 hr; IFF, 44 hr; NAS, 42 hr; UHF, 26 hr; HF, 36 hr; TC, 54 hr; ECM, 26 hr; IR, 36 hr; RHAW, 60 hr; CMRS, 32 hr; Pen Aids, 57 hr.

surveys, conferences, and studies (including the study on which this report is based). A major consequence of these activities was that ATC moved set school to the FTDs at the operating bases.*

On the Job Training

Upon graduation from set school, the airman is assigned to an Avionics Maintenance Squadron at an operating base, where he is supposed to enter the OJT program. The Air Force views OJT as "a systematic, reportable application of self-study and craftsman-apprentice principle. The trainee acquires AFS knowledge by enrolling in and studying Career Development Courses; he acquires job proficiency while performing on the job under supervision of a skilled worker."**

The Career Development Course is the self-study portion of OJT. When the airman enters the OJT program he receives the first of the CDC packages, usually prepared in volumes of related topics, and studies it on his own. When he feels he is ready, he takes a Course Examination to test his mastery of the subject matter. Generally there is a time limit beyond which he should not wait to take the examination.

The CDCs in a given field are written in the curriculum units at the technical centers that provide the basic technical course in the field. Thus, they tend to reflect much of the material of the basic course and are geared to the STS. The review, publishing, and distribution of the CDCs and processing of the examinations are administered by the Extension Course Institute of the Air University.

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*This change is addressed in more detail in Sec. IV.

**AFM 50-23, Guide for Planning and Conducting On-the-Job Training, p. 1-2. See also AFR 50-26.

If CDCs are not available, the study references listed in the STS provide materials for career knowledge training.* They are generally Air Force Manuals and technical orders. Completion of study of the references is documented on the man's personal copy of the STS. The CDCs for 326X2A and 326X2B became available in April 1974 and for 326X2C in July 1974.** In either case, the STS plays a major role in defining the content of the knowledge aspects of the OJT program. The result was that in the 326 AFS, the CDC reflected the representative training concept devised at Lowry AFB and was tied to the particular models of F-111 for which Lowry AFB had training equipment.

Paralleling the self-study program, job proficiency training is carried out in each operational unit.*** The new 3-level is assigned to a more experienced person, usually a 5-level, who is responsible for training him to perform tasks to the proficiency specified in the STS for the 5-level. The Air Force stresses that the essential feature of this procedure is "the close association between the trainee and the trainer."****

On each man's personal copy of the STS are recorded the dates he began and satisfactorily completed training for each task listed in the STS. When his trainer believes he has mastered a given task to the degree of competence indicated in the STS, the 3-level is checked out by his supervisor and, if satisfactory, the task is signed off in

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*AFM 50-23, Guide for Planning and Conducting On-the-Job Training, p. 7-3.

**ECI Catalog and Guide for Extension Course Administration, Extension Course Institute, Air University, Gunter AFB, Alabama, October 1, 1974.

***See AFM 66-1, Vol. V, pp. 1-3.

****AFM 50-23, Guide for Planning and Conducting On-the-Job Training, p. 1-10.

his STS. Before a given task is signed off, the 3-level may not perform it without supervision by a 5-level or higher. In addition, a man cannot be upgraded to 5-level until all tasks he is working on have been signed off in the STS.

Field Training Detachment Courses

ATC also operates about 70 FTDs, which work with the operating commands to update maintenance crews when new equipment is phased into the field and to provide other on-site training support.* The FTDs are controlled by Sheppard Technical Center, but a large part of their established syllabus originates in the FTD itself and is reviewed by the curriculum units of the Technical Training Centers that teach the basic courses in the specialties concerned. The FTDs also devise courses to fill on-site needs for such special skills as microminiature soldering. Satisfactory completion of courses in the established FTD syllabus often earns an airman credit in the Community College of the Air Force.

Table 8 shows the established FTD courses that support the 326 AFS. There are no FTD courses for the intermediate and AGE maintenance shops because the test stations that would be required to support such courses are considered too expensive to be dedicated to FTD use. There is justification for this viewpoint, since FTDs typically train very few students at any one time in a given specialty so that test stations dedicated to training might be unacceptably underutilized.

*See AFM 50-29, Field Training Program.

Table 8

FIELD TRAINING DETACHMENT COURSES FOR 326 AFS

AFSC	Title	Command	Base	System	Effective Date	Length, hr	Course Content
3267A	Integrated Avionics Systems Technician	TAC	Cannon	F-111D	17 January 1973	360	Introduction, 42 hr; Computer, 54 hr; INS, 48 hr; Doppler and HSD, 42 hr; IDS, 36 hr; TFR, 48 hr; ARS, 90 hr.
					5 October 1973	168	Introduction, 12 hr; Computer, 24 hr; INS, 20 hr; Doppler and HSD, 24 hr; IDS, 24 hr; TFR, 24 hr, ARS, 40 hr.
		TAC	Nellis	F-111A/E	15 August 1972	250	Introduction, 16 hr; ARS, 68 hr; ODSS, 28 hr; INS, 48 hr; TFR, 44 hr; Integration, 46 hr.
		TAC	Mt. Home	F-111F	2 April 1974	180	DCC and CDS, 40 hr; INS, 20 hr; ODSS and DBT, 20 hr; LARA and TFR, 40 hr; ARS, 60 hr.
		SAC	Plattsburg	FB-111A	21 December 1973	186	Introduction, 12 hr; INS, 174 hr.
					21 December 1973	228 } 506	Introduction, 12 hr; ARS, 132 hr; TFR, 84 hr.
					21 December 1973	92	Introduction, 12 hr; HSD, 24 hr; ODSS, 17 hr; EAS, 15 hr; NRS, 24 hr.
3267B	Integrated Avionics Systems Technician	SAC	Plattsburg	FB-111A	25 September 1972	198	Introduction and Engine, Position, Pneudraulic and Liquid Quantity Systems, 48 hr; Pitot Static and CADS, 36 hr; AFRS, 24 hr; Primary Flight Controls, 30 hr; Stability Augmentation and AFCS, 60 hr.
3267C	Integrated Avionics Systems Technician			F/FB-111	17 June 1974	204	Communication Systems, 48 hr; Navigation Systems, 54 hr; RHAWS, 54 hr; Other ECM, 48 hr.

It may be noted that the Strategic Air Command has a much more intensive FTD program than does TAC. For example, SAC's FTDs offer about 500 hours in FB-111A training for the 326X2A field, whereas the course at Cannon AFB for the F-111D (a more complex aircraft) covers the same material in 168 hours.

Table 8 does not show the many ad hoc and site-specific courses offered by the FTDs to meet special needs. These courses are not part of the established syllabus, and their existence often depends on the aptitudes of particular FTD instructors as well as on special site needs.

Finally, the established FTD courses are denoted as 7-level courses, implying that they are intended to contribute to a 5-level's upgrading. In fact, however, most 3-levels enter the FTD course (if one exists) shortly after they arrive on base rather than starting on OJT. This may be because the representative training at Lowry AFB is unable to deal with important differences among the F-111 models.

III. DEVELOPING THE REQUIREMENTS FOR TRAINING

Because the F-111 required such a radical departure from the previous procedures for maintaining avionics systems, and to ascertain the requirements for training, we undertook several efforts to understand the job of maintaining this new generation of avionics equipment.

PROCEDURES FOR SURVEYING JOB CONTENT*

A unique data collection effort was required to establish the content of the job. Occupational surveys were not available for avionics flight-line maintenance (the first flight-line job inventories for the 326X2A and 326X2B occupations were published in April 1976). Of the several ways for gathering job-related information--occupational survey, questionnaire, checklist, individual interview, and observation interview**--the Air Force rates the observation interview highest in terms of the specificity, completeness, and accuracy of the information obtained. "Of the methods described, the observation interview is preferred because it reveals unique tasks and provides a better understanding of the work performed."*** In many cases, this better understanding consists of

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*The work on which this section is based is reported in detail in Analysis of the Content of Advanced Avionics Maintenance Jobs, by Polly Carpenter-Huffman, John Neufer, and Bernard Rostker, R-2017-AF, The Rand Corporation.

**See AFM 50-2. An observation interview is conducted at the work site and concerns current work.

***AFM 50-2, p. 28 (emphasis added).

an appreciation of the knowledge required for task performance, the most significant aspect of the task as far as training is concerned. This information can rarely be elicited in any but a face-to-face interview because of the potential variety of possibilities and because of the disinclination of most job incumbents for writing accurate descriptions of any length. As a result, we used observation interviews in our job content survey.

The Survey Population

The job content survey examined maintenance as carried out by the three Avionics Maintenance Squadron flight-line shops. Normally personnel from one of the three shops are dispatched to correct a system malfunction, which is reported by aircrews during the post-flight debriefing. An effort is generally made to let a 3-level airman work with a 5-level for OJT.

To facilitate rapid maintenance action before an aircraft launch or immediately after an aircraft lands (while power is still applied to the various avionics systems), a special multi-shop team was established. At Cannon AFB, this team is referred to as "Roadrunner."* The Roadrunner team, stationed on the flight line, has its own truck, carries its own spare LRU parts, and is made up of experienced personnel from each shop. Roadrunner duty places greater stress on treating the avionics system as an integrated whole and quick turnaround action than does a conventional shop. Jobs performed by the Roadrunner team were also included in the survey.

*At Mountain Home AFB, the team is known as Big D, the D standing for diagnostic. At Plattsburg AFB, the team is called the Big Apple.

Survey Procedures

During initial development of survey procedures, it soon became apparent that, in order not to disturb normal work patterns and to maximize the number of cases an interviewer could efficiently handle, the best approach was to debrief the maintenance team immediately after completion of a job. These interviews were conducted at Cannon AFB during the first two weeks of April 1975. Immediately after completing a maintenance assignment and the required 349 form, the maintenance crew joined the interviewer in a room adjacent to the flight-line shops. The interviewer copied the 349 data and indicated his desire to know, step by step, how the crew performed the assignment just completed. The "flow chart" nature of the survey form enabled the interviewer to record the logical decision/activity process. The activity sequence was drawn out by asking such questions as:

What did you do first? Why?

What did you do next? Why?

Have you left out any steps?

Did that complete the job?

After we obtained the sequence of steps from start to finish, we asked the interviewee, at each step, whether he used technical orders and where he learned to choose and perform that step.

During the interview period, April 1 through April 11, 1975, we completed 141 interviews. Since some maintenance assignments consisted of more than one job action, the interviews yielded 188 AFTO 349 job entries--96 from Bomb/Nav, 42 from Instrument/Autopilot, and

50 from Comm/ECM. (We assigned each Roadrunner job to the shop maintaining the affected system.)

Expert Review

In May 1975, a Rand team revisited Cannon AFB to validate the field observations. One or more experienced maintenance men from the appropriate shop was interviewed on each job write-up. With only two exceptions, the experts were sergeants with current flight-line experience. The expert was asked to comment on the completeness of the write-up and, based on it, to judge the appropriateness of the actions taken. These comments are included in the final summary write-up under "Expert Comments."

Representativeness of the Job Content Survey

We were concerned that the survey be representative of the normal work of the avionics flight-line shops. The interview-debrief techniques, followed by expert review, were designed to assure completeness and accuracy in recording the job content of those jobs surveyed. There was, however, no built-in guarantee that the sample would be representative. Although the interviewers made it a point to work all shifts, there was no attempt to prescreen interviews to ensure a representative sample. In fact, however, the sample was representative of normal work patterns. To verify this, we checked the survey observations against Base Level Inquiry System (BLIS) data for the months of March and April 1975. A statistical test verified that the sample did not significantly differ from the work unit distribution of jobs performed in those two months. To test if the

sample was representative of the types of actions normally performed, the 349 Action Taken Codes were statistically compared with the BLIS records for the same period--the first two weeks of April. Again, the sample appears not to be unrepresentative of the normal work pattern.

SURVEY RESULTS AND DIAGNOSTIC TECHNIQUES

The purpose of the job content survey was to make an accurate record of the major steps followed in the maintenance of avionics equipment on the flight line and to identify the techniques used in the job. The 188 flight-line jobs observed at Cannon AFB resulted in major maintenance actions in the following nine work categories: AGE setup, troubleshooting, operational checkout, remove/install, minor repair, checking, adjustment/alignment, test/inspect, and safety wiring. Table 9 shows the distribution of major maintenance actions by shop. Since more than one action may have been taken on a single job, the total number of actions is larger than the total number of jobs.

The most important maintenance actions observed in the job survey were troubleshooting and operational checkout. Troubleshooting is any action undertaken to isolate the cause of a discrepancy. It generally leads to the replacement of an LRU, i.e., a remove/install action. In a small number of cases, the LRU is adjusted or calibrated without removal from the aircraft. Operational checkout is a prescribed procedure to verify that a system is performing properly. It generally follows troubleshooting and the installation of an LRU or a repair, align, adjust, or calibrate action.

Table 9

CANNON JOB CONTENT SUMMARY: NUMBER OF JOBS WITH EACH TYPE OF ACTION

Type of Action	Bomb/ Nav	Instrument/ Autopilot	Comm/ ECM
AGE setup	38	15	15
Troubleshooting	55	18	22
Operational checkout	27	16	10
Remove/install[a]	67	24	28
Minor repair	1	2	1
Check[b]	12	8	8
Adjust/align	5	2	3
Test/inspect	0	1	0
Safety wiring	0	6	0
Total jobs[c]	96	42	50

[a] Each removal or installation (R/I) is counted as one action; thus a "remove and replace" is two R/I actions.

[b] Less than full operational checkout.

[c] Since several actions may have been taken on a single job, this is not necessarily the sum of the column above.

The least prevalent actions were repair, check, align, and inspect; they occurred in only 26 percent of the jobs. In most cases, they were routine and undemanding. Safety wiring is an Instrument/Autopilot job that entails inserting steel wires in screws and/or cannon plugs to ensure that they remain secured. The operation is basically mechanical and requires some manual dexterity.

The troubleshooting work category is by far the most important, in terms of maintaining the aircraft in good working order and in its requirement for job knowledge and training. As a part of the job content analysis, we were particularly interested in the techniques used to perform these tasks. Table 10 gives the major diagnostic techniques used in the 95 troubleshooting jobs. Although usage differs by shop, the major patterns are clear. On the average, two techniques were used in the Bomb/Nav shop, whereas the other two shops required only one.

The major diagnostic techniques are described below.

Computer addressing is the technique most used in Bomb/Nav jobs. Input and output are through the Navigation Data Entry Panel. This procedure uses the computer memory's ability to retain information on LRU malfunctions. The technical order contains numerical input codes ("error trap addressing") for the various systems and output codes with a list of likely LRU failures. This technique, however, was originally not part of official troubleshooting procedure: the computer memory address codes were used to develop the computer programs (software) by the contractor's systems programmers and were first published only in the operational checkout manual for aircrews. Through local usage at Cannon AFB they have become accepted

Table 10

CANNON JOB CONTENT SURVEY: NUMBER OF TROUBLESHOOTING JOBS USING VARIOUS DIAGNOSTIC TECHNIQUES

Diagnostic Technique	Bomb/ Nav	Instrument/ Autopilot	Comm/ ECM
Computer address	33	0	0
Built-in test equipment (BITE)	18	7	9
Video display	22	8	1
Audio display	3	0	7
Maintenance control unit (MCU)	1	0	0
Diagnostic R/I[a]	25 (84)	1 (2)	7 (22)
Special test	1	2	4
Total jobs	55	18	22

[a] Numbers in parentheses are total number of R/I actions.

flight-line troubleshooting procedure and were recently incorporated in provisional maintenance technical order revisions.

The computer, however, does not provide an unambiguous fault-isolation capability. Judgment is needed to choose the appropriate code and interpret the computer readout. Comprehensive knowledge of integrated avionics and system data flow are required to exploit this technique properly.

The BITE system and the Avionics Test Panel (ATP) are major troubleshooting techniques. Either automatically or in response to a test by the aircrew or maintenance personnel, the BITE system causes a fault legend light to appear on the ATP or a meter to deflect and reveal the operational status of an LRU. Although the tests are simple to operate, like computer addressing they can lead to ambiguous or incorrect conclusions regarding LRU status. Usually the BITE/ATP indication is verified by replacing one of the indicated LRUs.

Observation of video and other displays is a very common diagnostic technique in the Bomb/Nav and Instrument/Autopilot shops. These procedures usually require a high degree of judgment and advanced knowledge of how the integrated avionics components are tied together. Improper output display could be caused by the display unit itself, the computer, the sensor device, or the wiring. This technique is analogous to troubleshooting a home television set when the main indication is the quality of the picture.

Observation of audio signals is the primary diagnostic technique used on the communication equipment. The technician operates the various systems in their normal manner and listens to the quality of the audio.

The removal and installation of an LRU is not only the culmination of troubleshooting but in many cases is a diagnostic technique itself. A diagnostic R/I sometimes consists of using an available spare from supply or the shop to confirm a malfunction. When spares are not available, LRUs are swapped between aircraft, the presumably good LRU being returned to the original aircraft after confirmation of the malfunction. In some cases, when spares are not

available and swaps are made, LRUs are removed and sent to the shop on the basis of a best guess, without strong supporting information.

Many of the R/I actions in the job content survey (45 percent) were for diagnostic purposes, as shown in Table 11. Thirty-five percent of the troubleshooting jobs used the diagnostic R/I as an important troubleshooting technique. On these jobs an average of 3.4 R/I diagnostic actions were recorded. The R/I average is 1.8 on troubleshooting jobs where no diagnostic R/Is were performed.

Table 11

REMOVE AND INSTALL ACTIONS BY TYPE OF JOB

Type of Job	Number of Jobs	Total R/Is	Diagnostic R/Is
Troubleshooting with R/Is	61	164	108[a]
Operational checkout	28	40	--
Other jobs with R/Is	31	38	--
Jobs without R/Is	68	--	--

[a] Diagnostic R/Is occurred on only 33 of the troubleshooting jobs. The total R/Is for all purposes on these 33 jobs was 112.

The F-111D was designed so that a minimum of special test equipment would be needed on the flight line to maintain the avionics system. Special test equipment was more frequently employed as a diagnostic aid in the Instrument/Autopilot and Comm/ECM shops than in the Bomb/Nav shop. In general, this equipment merely required the reading of dials or go/no-go indicators. The analog in civilian uses is the commercial vacuum tube tester. Although the tube tester is a precision measuring device, it is easy to set and provides an easily understood good/bad readout. Such devices permit novices to check vacuum tubes adequately.

The Maintenance Control Unit, unique to the Mark II, is designed to print fault codes indicating specific LRU failures. According to the Attack Radar and Terrain Following Radar System Technical Manual, "Troubleshooting ... consists of observing FAILURE STATUS lamps on the AVIONICS TEST PANEL and reading the printout of the MCU ... to determine malfunctions.... [However], further troubleshooting may be performed if built-in tests do not isolate to the malfunction."*

The survey shows that the MCU is not being widely used as a diagnostic aid. It was mentioned in only two job interviews, once as a diagnostic aid and once as an LRU to be repaired. In the latter case, it was repaired last, instead of first, when it might have been used in troubleshooting other systems. The MCU printout is not used because the airmen have found that it may reflect transient malfunctions and cannot be relied upon to pinpoint LRU failures.

*TO IF-111D-2-5-2-1, p. 2-4.

This discussion has concentrated on major diagnostic techniques used to troubleshoot the Mark II system. Equally important is the identification of diagnostic techniques not used. The job content survey revealed that diagnostic techniques associated with basic electronics were rarely used. This was hardly a surprise given the design of the LRUs, which, for most purposes, can be viewed as sealed containers. Field maintenance personnel do not have access to the internal circuitry of the LRU. In fact, in only one case was a knowledge of basic electronic principles used and that was by a Technical Representative from General Dynamics.

EFFECTS OF SYSTEM INTEGRATION ON FLIGHT-LINE MAINTENANCE

The integration of advanced avionics affects flight-line maintenance in several ways. First, malfunctions often occur in several systems at once. Table 12 shows the various system malfunctions per sortie flown by one aircraft as part of a General Dynamics test program. Similarly, Fig. 2 shows the Field Observation Summary for Rand ID Job 105. In this job, problems were encountered on the following systems:

- o Data Panels and Controls
- o Inertial Navigational Set
- o Terrain Following Radar Set
- o Altimeter Set
- o Attack Radar Set

First, because of the integrated design of advanced avionics systems, malfunctions in one system often affect the

Table 12

GENERAL DYNAMICS TEST AIRCRAFT 68-150:
NUMBER OF MALFUNCTION WRITEUPS

Flight Number	Malfunctioning System[a]									Total Reports
	ARS	DRS	IDS	DCC	INS	HSD	SMS	MCU	OFP	
1			1							1
2					1					1
3										0
4								1		1
5	1			1						2
6	1									1
7			1							1
8			3							3
9				1						1
10					1					1
11		1	1		1			1		4
12			2						1	3
13	1		1	1					1	4
14		1		2					1	4
15		1	1	1					1	4
16	1	1		1						3
17		1								1
18	1	1								2
19	1	1	1		1					4
20		1		1	1					3
21				1						1
22			1	1						2
23			1	1						2
24										0
25	1							1		2
26			1						1	2
27				1						1

[a]
ARS: Attack Radar System
DRS: Doppler Radar System
IDS: Integrated Display Set
DCC: Digital Computer Complex
INS: Inertial Navigation Set
HSD: Horizontal Situation Display
SMS: Stores Management Set
MCU: Maintenance Control Unit
OFP: Operational Flight Programs, i.e., the computer software.

FIELD OBSERVATION SUMMARY

Page 1 of 3

Rand ID 105 Work Center 24360 System 73H,K,S+C

349 Data

	1	2	3	4	5
JCN	0980754	0980749	0980752	0980751	0980753
TM	B	B	B	B	B
WUC	73 KBO	73 HOO	73 HPO	73 SDO	73 CAP
AT	R	L	L	R	H
WD	D	D	D	D	D
HM	242	127	127	242	799
Start:	08:1900	08:1600	08:1800	08:1700	08:2000
Stop:	08:2000	08:1700	08:1900	08:1800	08:2100
Skill	5	5	5	5	5

NARRATIVE OF MAINTENANCE ACTION:

The discrepancies reported were:

1. Erratic video in both TFR channels
2. Excessive drift in the INS
3. The EPU fails the range test
4. Could not monitor the NDEP
5. Problems with LARA

Activity Sequence

1 Set up -60, -10 AGE

2 Turned on all avionics systems

3 Checked LARA: Bit lite

Good

4 Addressed computer via NDEP

Checked OK (CND)

5 Checked EPU re range tests

CND

6 Attempted readouts of INS on NDEP

Bad

7 Remove and replace NDEP

Fig. 2—Field observation summary: Example 1

FIELD OBSERVATION SUMMARY

Page 2 of 3

Rand ID 105 **Work Center** 24360 **System** 73H,K,S+C

NARRATIVE OF MAINTENANCE ACTION (Cont.):

The second, third, and fifth systems checked OK , i.e., CND. For the fourth the NDEP was removed and replaced. The TFR channels were retuned and the left antenna replaced.

The Technical Order procedure was followed closely in tasks 5 and 10; and it was referred to during tasks 9 and 11. Other tasks were done from memory.

The performance of these tasks had been learned almost entirely from MISD training, with some help from OJT, and none from technical school or FTD.

EXPERT COMMENT:

Should also check Test Altitude on LARA: also check BIT on NDEP.

AIRCRAFT FOLLOWUP:

1st Action (73K): Several TS actions were completed, the last being Bench Check Serviceable with 799 (no defect). A 73K discrepancy write-up on next flight produced no 349 data.

2nd & 3rd Actions (73H): Each action taken code indicated adjustments, but MM says all were CND. Next sortie 73H write-up became a WUC 51E99 action.

4th Action: TS found "no defect" (BC serviceable); no report next sortie.

5th Action: No problem next sortie.

Activity Sequence

8 Checked NDEP--read INS output

Good

9 Checked TFR, both channels

No fail lite but display poor

10 Sought to improve video; retuned both antenna/receiver channels

11 Repeated video checks of TFR displays

Better video but still unsatisfactory

12 Requested Tech. Rep. assistance

13 Hooked up breakout box to allow test access to LRU circuitry

14 Checked pulses with oscilloscope using breakout box

Poor scope presentation

Fig. 2— (continued)

FIELD OBSERVATION SUMMARY

Page 3 of 3

Rand ID 105 **Work Center** 24360 **System** 73H,K,S+C

Activity Sequence

15 Tech Rep suggested receiver antenna replacement--this was done

Better but not completely satisfactory

16 Wrote up for in-flight checkout

17 Checked INS drift via NDEP readouts

Within tolerance

18 End of Job

Fig. 2— (continued)

performance of others. For example, Table 12 shows an Attack Radar System malfunction on flight 13. The discrepancy was "ARS video weak and lost sweep on ground." The General Dynamics Fault Isolation Verification Program (FIVP) team found that "weak video seemed to be related to STU (Signal Transfer Unit, a LRU in the Integrated Display Set)." However, an EPU (Electronic Processor Unit, a LRU in the ARS) was removed because "malfunction seems to indicate that the EPU was failing intermittently." On a previous flight, the FIVP team attributed this discrepancy to a bad Multi-Sensor Display, another LRU in the Integrated Display Set. Similarly, on the job shown in Fig. 2 the maintenance technician attributed an Inertial Navigation Set problem to a faulty Navigation Data Entry Panel. Subsequent check of 349 data shows that no defects were detected on the Data Entry Panel in the shop and the Inertial Navigation Set failed on the next flight.

Second, avionics system malfunctions do not always honor the divisions between the three flight-line maintenance specialties. We found, for example, that both the TACAN (Tactical Air Navigation) and ILS (Instrument Landing System) in Comm/ECM may be affected by failures in Bomb/Nav systems. An example is provided by Rand ID No. 60, shown in Fig. 3.

Third, unlike the maintenance of previous avionics systems, maintenance of F-111 avionics equipment requires technicians to use the fault-isolation capability built into the system. This would make the job easy and routine if the BITE provided unambiguous indication of LRU failure. Such is not the case. Because of generally poor fault-isolation capability on the F-111D Mark II, the F-111 Special Projects Office contracted with General Dynamics to study fault

FIELD OBSERVATION SUMMARY

Page 1 of 1

Rand ID 60 Work Center 24370 System 71C

349 Data

	1	2	3	4	5
JCN	0920772				
TM	B				
WUC	71 COO				
AT	H				
WD	D				
HM	812				
Start:	03 1700				
Stop:	03 1730				
Skill	5,5				

Activity Sequence

1 Sought to learn problem source

Learned from A Shop

2 Found ILS OK now

"A" Shop action had corrected

3 End of job

NARRATIVE OF MAINTENANCE ACTION:

The report was lack of an ILS display. *Investigation re-vealed* that A Shop had fixed the DCC problem of the aircraft and that this ILS problem no longer existed.

EXPERT COMMENT:

1st--JSA.

2nd--Not clear what MM did. Very possibly he accepted A Shop's word that the ILS problem had been corrected.

AIRCRAFT FOLLOWUP:

Record shows only one A Shop action following a 73H discrepancy report; result was an R&R of the Flight Director System Coupler (51BB0). The TS could find no defect. No further 71C discrepancies arose in April sorties.

Fig. 3 — Field observation summary: Example 2

isolation on the F-111D. The 1974 General Dynamics FIVP team concluded that the fault-isolation capability was inadequate because:*

1. Avionics Test Panel legends and Maintenance Control Unit printouts indicate failures when no faults are present in the system.
2. Faults occur that are not indicated by the ATP and/or MCU printouts.
3. In a failure, the incorrect LRU may be indicated as faulty.
4. The flight-line technical orders and special troubleshooting are incomplete or erroneous in many cases.

To overcome these shortcomings, and because of the idiosyncratic nature of each advanced integrated avionics system, maintenance technicians need a thorough knowledge of the particular avionics system they are going to work on. For example, on the F-111D the Attack Radar System feeds data to the Digital Computer Complex and the Integrated Display Set. General Dynamics noted that depending on the type of signal, mode of operation, operator action, and timing of output, the fault status indication of a particular LRU may or may not be valid. A failure in a particular mode can be caused by a problem in any one of five LRUs, which are classified in two major systems. Isolating a malfunction in this mode requires a "thorough understanding of the mode of operation."** In another case, they found the fault-isolation capability to be ambiguous, with most faults being

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*F-111D Mark II Fault Isolation Verification Program (FIVP), Final Report, Vol. I, Analysis, General Dynamics Corporation, Convair Aerospace Division, Fort Worth, Texas, FZM-12-8308, July 1, 1974, pp. 1-4.

**FIVP, Vol. I, p. 2-115.

the "result of a malfunction of another system, another LRU within the system or an operator procedure error."

Effective use of the BITE requires that maintenance personnel be educated in the use and interpretation of the MCU printout, which must be read in combination with the original "squawk," indications from the BITE, and computer readouts. In many instances, the sequence of MCU printouts must be related to the sequence of tests run through the computer to isolate the faulty LRU. It can no longer be assumed that troubleshooting consists of observing a BITE/MCU code and removing an LRU.

The key to effective and efficient maintenance work is the ability to use all diagnostic tools to increase the accuracy of diagnosis and to decrease the time expended on maintenance actions. Choosing the appropriate sequence of actions is the demanding aspect of maintenance. Although designed to indicate the systems at fault quickly and clearly, the Mark II avionics system's diagnostic aids do not provide unequivocal information. Thus, the maintenance technician must play detective, developing clues and interpreting them as he works through the interrelationships of the system and using a mix of diagnostic techniques in his search for the one or more defective LRUs.

THE NATURE OF FLIGHT-LINE MAINTENANCE

Jobs in the Bomb/Nav specialty can be very complex because the avionics systems are highly integrated and fairly unreliable, and because maintenance personnel must rely on indirect indications of faults (provided by the system) that are ambiguous. A large number of

Bomb/Nav jobs (over half in our sample) require troubleshooting. In many, maintenance personnel must know how to use a combination of diagnostic techniques to resolve ambiguities. Proficient fault isolation of Bomb/Nav systems often also requires knowledge of the idiosyncrasies of the avionics package, that is, of how the components and the LRUs within them interact in various operating modes.

The Instrument/Autopilot and Comm/ECM specialties are less difficult. Troubleshooting is required somewhat less often, and fault isolation usually requires only one technique. There is more stress on interpretation of video displays in Instrument/ Autopilot and more on audio in Comm/ECM. Neither specialty uses the computer as a diagnostic aid. Both, especially Comm/ECM, occasionally use special test sets. Systems in these specialties are less highly integrated than are the Bomb/Nav systems, although there are some interactions among systems and between Comm/ECM systems and Bomb/Nav systems. Some operational knowledge of particular avionics systems would appear to be useful for Comm/ECM (and should not be ruled out for Instrument/Autopilot), but less depth of understanding is required than for Bomb/Nav.

IV. REVIEW AND EVALUATION OF TRAINING IN THE 326X2 CAREER FIELDS

In the previous section, we examined the job of maintaining on the flight line the new generation of advanced avionics. In this section, we examine in detail the way airmen are trained in the 326X2 AFS. We concentrate on training for the Bomb/Nav shop (326X2A), discussing training in that specialty as it was until the autumn of 1975, and recent modifications, current training in the other flight-line specialties, and TAC's Task Oriented Training program.

BASIC TECHNICAL TRAINING IN THE BOMB/NAV SPECIALTY BEFORE AUTUMN 1975

Even before Rand began its study of avionics training, there were strong indications that something was wrong with 326XX training. In the spring of 1974, the Avionics Superintendent Steering Group (ASSG) concluded that:

> In the past six years, several new (F-111 model) aircraft have proliferated into inventory. This has overextended the scope of the 326XX ASC. The training of personnel for the early AFSC structure was ... considered adequate at its inception. However, as the scope of the AFSC structures was extended, the training concept did not meet the needs of the users....
>
> Representative training involves training on a selected item of equipment which is similar to or representative of one or more other pieces of equipment. However, for the 326XX AFSC, the equipment used for training is only partially representative of the equipment that the trainee will encounter in the field. Previous meetings and studies have concluded that the present representative training concept is not meeting the demands of the users....
>
> This committee recommends that representative training be replaced with weapons systems oriented training.

However, what the ASSG did not note was that specific weapons systems training is necessary, but not sufficient, to ensure adequate job training.

In examining 326 training, we found that, independent of the representative training issue, the basic three-level Bomb/Nav course at Lowry AFB did not stress the skills that airmen needed and used on the job. Table 13 shows the Plan of Instruction (POI) for the basic course through which most of the current (first-term) maintenance force has passed. It shows a heavy emphasis on basic theory (30 percent) and systems familiarization (49 percent). Instruction of actual job performance was limited to 64 hours or 11 percent of the course, with only half of that "hands on" experience on trainers. Moreover, the trainers themselves were not sufficiently linked together to provide a reasonable facsimile of an integrated avionics system.

The course first exposed the student to six weeks of basic electronics theory, covering such topics as Series-Parallel Circuit Analysis (6 hours), Vacuum Tubes and Tube Testing (6 hours), and Semiconductor Theory and and Solid-State Diodes (7 hours). Based on our job content analysis, we cannot relate these topics to actual job procedures. Moreover, these topics are not even related to subsequent instruction in the Bomb/Nav POI.

After completing basic electronics, the students received instruction in each individual avionics system. The skills taught were abstract and only indirectly related to job performance. For example, instruction in the Attack Radar System began with 15 hours of familiarization with operational and performance characteristics.

Table 13

ANALYSIS OF PLAN OF INSTRUCTION FOR COURSE 3ABR32632A

(Course hours)

					Subsystems								
	Total	Per-cent	Mainte-nance Elec-tronics	Intro-duction	INS	ODSS	CDC/DCC	ARS	TFR	DR	LARA	Systems Inte-gration	Inte-grated System Perfor-mance
Basic theory	174	30.1	174	--	--	--	--	--	--	--	--	--	--
Applied theory	9	1.6	--	--	9	--	--	--	--	--	--	--	--
Familiarization	126	21.8	--	12	9	9	30	15	6	6	3	6	6
Block analysis	157	27.2	--	--	5	8	--	45	36	12	6	45	--
Ops check procedures	10	1.7	--	--	--	--	--	--	--	--	--	--	10
Ops check hands-on	21	3.6	--	--	--	--	--	--	--	--	--	--	21
Test station procedures	23	4.0	--	--	4	1	4	4	3	4	3	--	0
Test station hands-on	10	1.7	--	--	--	--	--	--	--	--	--	--	10
Course mechanics	21	3.6	--	2	3	--	2	2	3	--	2	3	4
Maintenance procedures	27	4.7	--	24	--	--	--	--	--	--	--	--	3
	578												
Totals													
Basic theory	174	30.1											
Applied theory	9	1.6											
System familiarization	283	49.0											
Cource mechanics	21	3.7											
Job performance	64	11.1											
(Procedures)	(33)	(5.7)											
(Hands-on)	(31)	(5.4)											

Next came 45 hours (1-1/2 weeks) in which students "trace the data flow ... [of various] circuits on functional block diagrams." The criterion objective* of this instruction was "given TO ... and simplified functional diagrams on [various] circuits, label missing pins, plug numbers and signal names," mastery of which is only tenuously related to job performance. Last, four hours were devoted to troubleshooting procedures. The instruction from the POI stressed theoretical rather than practical troubleshooting, i.e.:

> Discuss the procedures used for ARS troubleshooting. Using illustrations from the TO and troubleshooting logic diagrams, demonstrate how to isolate malfunctions to a line replaceable unit. Have the students complete all workbook projects.**

The criterion objective for troubleshooting procedures also stressed a rather artificial view of the technique: "Given the TO and a list of five ARS malfunctions, write the probable cause for each ARS malfunction."

After the student completed 221 hours of instruction on the individual avionics systems, he was given 54 hours on the integrated avionics systems. Most of this time (45 hours) the student traced functional diagrams. The performance part was 5 hours at the end of the course for the student to learn procedures for the operational checkout of four major systems--the Attack Radar System, Optical Display Sight System, Digital Computer Complex, and Control and Display Set. Moreover, he was not required to master these skills.

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*A criterion objective states the conditions under which, and the criteria by which, mastery is to be judged.

**POI 3ABR32632A.

The criterion objective required that given the technical orders he must "list the procedures for the operational checkout."

As the culmination of the course, the students were supposed to receive ten hours of integrated troubleshooting on bench trainers, but because of the size of the class, each student spent substantially less time on the trainer.

The above course of instruction seems to be only partially consistent with the 326X2A Specialty Training Standard and the requirements for awarding of the 3-skill level. The course may well provide sufficient "subject knowledge" to allow a student to "explain relationships and state general principles" about "attack radar systems major components, modes of operation and displays" as well as do a "functional block diagram analysis of attack radar systems." However, graduates of the course, according to the STS, should also be sufficiently proficient so that they can perform operational checks, remove and replace systems components, perform adjustment and alignment, perform self-test/BITE, and troubleshoot. They should be able to "do most parts of the task," needing "help only on hardest part." The course, however, does not require that a student accomplish any of these tasks before graduation.

The inadequacy of the 3-level course as training for job performance was verified in several ways. In the debrief interviews in the job content survey, we asked each technician about the source of training for the steps he was carrying out. The options included on the job training, Field Training Detachment, Task Oriented Training program (TOT), and technical school. Table 14 shows their responses.

Table 14

SOURCE OF PERTINENT TRAINING

(Number of Responses)

Shop	Technicians Interviewed	Training: OJT	FTD	TOT	Tech School
Bomb/Nav	67	67	14	5	5
Instrument/ Autopilot	37	37	1	--	7
Comm/ECM	34	34	21	--	3
Total	138	138	36	5	15

On the job training includes all experience acquired while a person is assigned to the flight line, whether or not he is under the guidance and direction of an official OJT trainer. The three-month-old TOT program was available only in the Bomb/Nav shop, where the technical school training course was given as the source of knowledge in only 5.5 percent of the responses.

The TAC questionnaire administered in early 1974 to a large number of 326 AFS personnel provides an additional means to evaluate the technical school training course, as well as the other 32632 courses. Since the questionnaire was unstructured, responses were not uniform and statistical comparisons cannot be made. However, the

general tone was quite clear; the respondents were critical of 32632 training in the following ways:

- o Basic electronics were irrelevant; training in fundamentals and systems were unrelated.
- o There was too much theory and not enough practical training; training equipment was not used or did not work; and training was too abstract.
- o Training was irrelevant to the job, and instructors lacked job experience.
- o There was too little training on systems integration and on troubleshooting integrated systems; too much training on inner circuitry.

In the spring of 1974, after trips to Nellis and Mountain Home AFBs, an Air Training Command evaluation team noted the following problems with the 32632A course:

- o More integration training involving the Digital Computer Complex is required.
- o Not enough performance training is given in technical school. Problems provided in technical training do not relate to actual problems.
- o Instructors are qualified to teach technical orders and theory, but they are not familiar with the aircraft.
- o Graduates are not familiar with the cockpit layout or with cockpit procedures.
- o Although the technical school teaches how to fill out forms, the graduates are not familiar with how, when, and why each form is used.
- o Training equipment is not working most of the time.
- o Graduates are not always assigned to FTDs at completion of residence training. Consequently, some graduates are not formally trained on maintenance of the inertial, doppler, Low Altitude Radar Altimeter, and Terrain Following Radar systems.

- Courses taught by the FTDs are redundant with Lowry AFB courses, i.e., graduates receive theory training on the same systems taught at Lowry AFB.

- Most graduates interviewed considered the Lowry AFB course inadequate for doing their job. Graduates and supervisors recommended that Lowry AFB provide electronics fundamentals and system principles training and let the FTDs and OJT provide the particular system training.

Unfortunately, the conclusions of the official Training Evaluation Report (LO 74-20), August 1974, touched only mildly on representative training and then noted that "This is a normal condition when the graduates may be assigned to more than one model aircraft." They did not mention any of the problems due to a lack of job performance training. The only recommendation was that "the training department take positive action to secure additional trainers."

TRAINING OF ADVANCED PERSONNEL IN THE BOMB/NAV SPECIALTY BEFORE 1975

Because avionics maintenance is idiosyncratic to different models of aircraft and because the job changes after the aircraft have been introduced in operating units, personnel newly assigned to maintain advanced avionics on particular aircraft need to be familiarized with the job, regardless of the extent of their prior experience. Such familiarization was supposed to be provided by the 7-level course given at the FTDs. There were three difficulties with the application of this policy: many new arrivals received no familiarization training, the 7-level course varied widely in thoroughness among the FTDs, and the quality of the 7-level courses was degraded because they were used to familiarize both neophytes and old hands simultaneously.

Although personnel transferred into the 326 AFS from other specialties were supposed to be cross-trained to the new specialty, usually at the FTD at the base of first assignment,* this policy frequently was not followed, primarily because of the need for senior personnel in the shop. Table 15 shows that nearly half of the 7- and 9-level personnel in the Bomb/Nav specialty at Cannon and Mountain Home AFBs had no formal training in the 326X2A specialty, according to their own reports. This problem is not peculiar to the 326 AFS, however. The Avionics Superintendent Steering Group noted in May 1974:

> In the past there was advanced 7-level formal training during the time when peculiar system training was provided at the entry level. That training was not supported by MAJCOM because they did not want to lose technicians for a period of time, so formal 7-level training was eliminated.... Now there is basically no formal, advanced training for avionics technicians. Advantages of implementing this type training would include: (1) A better technically qualified maintenance force, (2) Improved job motivation and satisfaction, (3) Improved systems reliability capability and MTBF, (4) Provide improved comprehension of complex system integration problems encountered by middle management.

The ASSG recommended that comprehensive 7-level courses be established at resident schools and that the training be mandatory for all AFSC 32XXX technical sergeants before they advanced to master sergeant.**

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*Personnel at and above the 7-level in the Bomb/Nav work centers generally were drawn from the 322 and 301 (now the 328) AFSs. For example, in September 1974 in the Bomb/Nav specialties at Cannon and Mountain Home AFBs, 60 percent of the men who identified their prior AFS had been 322s, 45 percent had been 301s (several had held both AFSs), and only one reported that he had had 3-level training in the 326X2A field. These data are derived from a survey Rand administered to all AMS personnel at Cannon and Mountain Home AFBs in September 1974.

**Report on Air Force Avionics Superintendent Steering Group (ASSG) 1974 Meeting, Attachment C.

Table 15

SELF-REPORTED EXPERIENCE AND TRAINING OF 7- AND 9-LEVELS IN THE BOMB/NAV SPECIALTY

	Percent of Respondents			
Base	(1) With Work on Less than Half of Systems in Previous 6 Months[a]	(2) With Limited F-111 Experience[b]	(3) With OJT on Less than Half of Systems[c]	(4) With No Formal Training in 326 AFS
Cannon	56	33	42	58
Mountain Home	50	38	55	36
Average[d]	53	35	48	48

SOURCE: Data on which this table is based are found in Tables A-1 and A-3 in the appendix.

[a] Does not include personnel assigned within previous six months.

[b] Includes personnel who worked both less than half of the systems during the previous six months and less than half of the systems during prior assignments to an F-111 base, if any.

[c] Includes personnel assigned within past six months if they reported working on more than half of the shop systems at a prior F-111 base.

[d] Averages weighted for different numbers of personnel in the two work centers.

Table 15 also shows that nearly half the respondents reported having had OJT on less than half of the systems assigned to their current work center and over half had worked on less than half of

these systems during the preceding six months. This general lack of contact with the job was partially ameliorated by prior experience, with only about a third reporting limited familiarity with the F-111 systems at any F-111 assignment. Even so, a relatively large number of supervisory personnel in the work center lack formal training in the job or have little day-to-day contact with it.

The design of basic technical training in the Bomb/Nav specialty also affected the advanced training given at the FTD. To compensate for the representative training given at Lowry AFB, the 7-level course was used at each base to familiarize the new 3-level with the resident F-111 model. The courses at the various FTDs were dramatically different in length, for reasons apparently unrelated to the complexity of the particular avionics systems. Table 16 compares the various 7-level courses at the FTDs. It may be seen that instruction on the ARS ranged from 34 hours at Cannon AFB to 126 hours at Plattsburg AFB. Systems integration was taught formally only at Nellis AFB.

Not only were new 3-levels sent to the FTDs, but other personnel new to the base, who already had flight-line experience with either the F-111 or other aircraft, were supposed to take the same course, so they too could become familiar with the particular F-111 model they would be working on. The result was that classes in the 7-level course were frequently composed of a mixture of neophytes and old hands. For example, in the five classes graduating from the 7-level course between June and November 1974 at Cannon AFB, the ratio of neophytes to more experienced personnel was 1.3:1, on the average.*

*Data derived from Rand 1974 survey mentioned earlier.

Table 16

7-LEVEL FTD COURSES 4ABR32672A

(Course Hours)[a]

	F-111 FTD Base			
Course	Cannon F-111D	Mt. Home F-111F	Nellis F-111A	Plattsburg FB-111A
Introduction	11	0[b]	15	30
DCC	22	38	(c)	0
INS	18	16	47	177
DRS	10	(c)	(c)	22
HSD	12	(c)	(c)	22
IDS	22	(c)	(c)	(c)
TFR	22	33	42	79
ARS	34	58	66	126
DBT[d]	2	3	(c)	(c)
ODSS	(c)	15	(c)	17
LARA		4	_	12
LCOSS[e]	(c)	(c)	28	(c)
Systems Integraton	0	0	44	0
Total	153	167	242	485

[a] Less measurement and critique hours.

[b] Integrated with course material.

[c] F-111 model does not have this avionics system.

[d] Dual Bombing Timer.

[e] Lead Computing Optical Sight System.

Because the FTD courses were taught as a group, the instructor had an almost insoluble problem--to give the new 3-level the training he needed without losing the attention of the old hand and to address the more sophisticated concerns of experienced personnel without going over the head of the neophyte. The result was a course that may often have been neither effective nor efficient for either group of students.

TRAINING IN THE INSTRUMENT/AUTOPILOT AND COMM/ECM SPECIALTIES

The job content analysis supported the common understanding that both of these specialties are less difficult than the Bomb/Nav specialty; therefore, deficiencies in training for them would be less damaging to job performance. In addition, maintenance of equipment associated with these specialties poses less of a problem for the AMS, so that the Air Force has been less concerned about possible shortcomings in personnel support for this equipment. Unfortunately, there is evidence that both specialties suffer from some of the same training problems as does the Bomb/Nav specialty. Since the training programs have not been revised (as has the training for Bomb/Nav), these deficiencies remain in the present programs.

Instrument/Autopilot

According to the chart for the basic course 3ABR32632B as of May 1973, 174 hours, or 45 percent, of the course was devoted to the study of equipment. The remainder was study of electronic principles (39 percent) and fundamentals (16 percent) such as maintenance management and the technical order system. The equipment taught and the hours devoted to each item are shown in Table 17. The training equipment came from the F-111A program.

Table 17

EQUIPMENT-ORIENTED PORTION OF COURSE 3ABR32632B, INSTRUMENT/AUTOPILOT

System	Hours
Engine instruments	36
Tachometer systems	(3.5)
Temperature indicating system	(4)
Variable reluctance pressure indicating system	(6)
Synchro indicating systems	(10)
Capacitance type liquid quantity indicating system	(10.5)
Oil quantity indicating system	(2)
Flight instruments	30
Pitot static system	(10)
Central air data system	(18)
Aircraft structural integrity program flight data recorders	(2)
Integrated flight and navigational instruments	54
Direct reading (standby) compass	(4)
Auxiliary flight reference system	(19)
Swing and compensation of the gyro stabilized magnetic compass system	(13)
Flight director system	(18)
Integrated flight controls	53
Flight controls	(8)
Trim systems	(7)
ASFC stability augmentation	(18)
Computer self-test	(3)
ASFC auto pilot	(8)
Automatic flight control systems (troubleshooting)	(9)

Graduates of this course who responded to the TAC questionnaire noted the same general type of training deficiencies as did graduates of the Lowry AFB course in the Bomb/Nav specialty, such as lack of practical training and irrelevancy of most basic electronics training to the job. The lack of practical training at technical school (at Chanute AFB in this case) undoubtedly explains why technical school was mentioned as the source of pertinent training for only 16 percent of the Instrument/Autopilot maintenance actions in the job content survey (see Table 14).

Finally, as in the Bomb/Nav specialty, personnel at the 7-level and above lack training and direct experience in the job. Of the 13 Instrument/Autopilot respondents to the Rand survey at Cannon and Mountain Home AFBs who identified their prior AFSs, 85 percent had formerly been 325s and 23 percent had been 422s.* Table 18 shows the self-reported experience and training of these personnel. Note that although respondents report themselves to be more deficient in both formal and on the job training than the Bomb/Nav personnel, they report greater direct familiarity with the job.

Communications/ECM

As mentioned previously, basic training for this specialty is given in a 9-week course at Keesler AFB, followed by a 10-week, equipment-oriented course at one of the FTDs. After this, the new 3-level is assigned to one of the F-111 bases, which may or may not support the model associated with the FTD that has trained him.

*Data from which these figures were derived are found in Tables A-1 and A-4 in the appendix.

Table 18

SELF-REPORTED EXPERIENCE AND TRAINING OF 7- AND 9-LEVELS IN THE INSTRUMENT/AUTOPILOT SPECIALTY

	Percent of Respondents			
Base	(1) With Work on Less than Half of Systems in Previous 6 Months [a]	(2) With Limited F-111 Experience [b]	(3) With OJT on Less than Half of Systems [c]	(4) With No Formal Training in 326 AFS
Cannon	20	0	83	57
Mountain Home	50	33	100 [d]	57
Average [e]	33	18	83	57

SOURCE: Data on which this table is based are found in Tables A-2 and A-4 in the appendix.

[a] Does not include personnel assigned within previous six months.

[b] Includes personnel who worked both less than half of the systems during the previous six months and less than half of the systems during prior assignments to an F-111 base, if any.

[c] Includes personnel assigned within past six months if they reported working on more than half of the shop systems at a prior F-111 base.

[d] Respondents apparently misunderstood question. Number not used in computing average.

[e] Averages weighted for different numbers of personnel in the two work centers.

Table 19 shows the major topics taught in these two courses and the hours assigned to each. Note that about a fourth of the total is directly related to job performance (operational checkout, troubleshooting, cable repair, and aircraft wiring). Of these hours, nearly half are devoted to teaching objectives that are tested by paper and pencil rather than by actual performance on a trainer or workbench. Even the 51 hours of training in operational checkout that are tested on a trainer cannot continuously involve the student in active performance because not all students can work on the trainer at once and because the instructor uses the trainer to demonstrate the checkout procedure before students try it.* Thus we may conclude that less than 10 percent of the course hours involve the student in active performance. Nevertheless, Table 14 shows that job incumbents cited the FTD as the source of pertinent training for 36 percent of the actions taken.

The Plan of Instruction exhibits other peculiarities. Cable repair, which is highly job-related and was cited by sergeants and staff sergeants on the TAC questionnaire as needing more training emphasis, is taught at Keesler AFB and not repeated at the FTD; certainly many trainees will have forgotten their training in this skill by the time they start work. Another peculiarity is the apparent redundancy of instruction in applied theory of specific systems; part or all of the 74 hours given this training at Keesler AFB is repeated at the FTD. Finally, no training in integrated

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*Data provided by the Mountain Home FTD for the period January-May 1974 showed that the Comm/ECM course produced an average of 0.1 trainer hours per student hour (total for all four trainers). The 51 trainer hours shown in the POI are 17 percent of the total hours for the FTD course.

Table 19

COURSE HOURS AND TOPICS FOR INITIAL TRAINING FOR 326X2C AFS

(Keesler AFB and FTD)

Topic	Hours -22C[a]	Total Hours	Percent Total
Orientation	44	56	10
Maintenance electronics	80	80	14
Communication systems fundamentals	36	36	6
Applied theory[b]	74	233	41
Operational checkout[b]			
Tested on trainer	0	51	10
Not tested on trainer	0	4.5	1
Troubleshooting (not tested on trainer)[b]	0	60.5	11
Cable repair	16	16	3
Aircraft wiring	6	6	1
Written tests	14	24	4
Total	270	567	

[a] Number of hours in Keesler AFB course.

[b] Specific communication system.

systems is designated at any point, although we know that at the least there are interactions among Comm/ECM and Bomb/Nav systems. In fact, a number of respondents to the TAC questionnaire expressed a need for more thorough training in systems integration.

The need for some training in systems integration implies that important features of the Comm/ECM systems are unique to particular models of F-111, that is, that some training specific to the weapon system is needed. Therefore, more effective and efficient training would result if the Comm/ECM specialist attended FTD at the base to which he will be assigned to duty.

Thus, we see that many of the same problems found in the Bomb/Nav training course are found in the Comm/ECM course, despite the greater opportunity provided by the FTD for job-relevant training. The practice of sending the trainee to Keesler AFB for fundamentals and to the FTD for set school, however, has disadvantages beyond the possible redundancy and loss of coherence between the two phases. Each time the trainee moves from one phase to the next, additional time and money are spent, not only during travel and relocation but because the trainee must often wait for classes to form. Lost time is not only lost money but unused (and hence forgotten) training. This is a serious defect of the two-phase training concept.

We found similar deficiencies in training and experience among 7- and 9-level personnel in the Comm/ECM specialty as in the Instrument/Autopilot specialty, as shown in Table 20, but Comm/ECM middle management had the poorest record of the three specialties in formal training.

Table 20

SELF-REPORTED EXPERIENCE AND TRAINING OF 7- AND 9-LEVELS IN THE COMM/ECM SPECIALTY

	Percent of Respondents			
Base	(1)[a] With Work on Less than Half of Systems in Previous 6 Months	(2)[b] With Limited F-111 Experience	(3)[c] With OJT on Less than Half of Systems	(4) With No Formal Training in 326 AFS
Cannon	40	40	17	33
Mountain Home	33	22	56	78
Average[d]	36	29	40	60

SOURCE: Data on which this table is based are found in Tables A-2 and A-4 in the appendix.

[a] Does not include personnel assigned within previous six months.

[b] Includes personnel who worked both less than half of the systems during the previous six months and less than half of the systems during prior assignments to an F-111 base, if any.

[c] Includes personnel assigned within past six months if they reported working on more than half of the shop systems at a prior F-111 base.

[d] Averages weighted for different numbers of personnel in the two work centers.

REVISIONS TO BOMB/NAV BASIC TECHNICAL TRAINING

As a result of concern about the effectiveness of representative training, and after several major conferences, a meeting was held at Lowry Technical Training Center (April 1-4, 1975) to develop a new training plan with two phases of instruction.

1. The preparatory phase includes basic electronics and digital computer fundamentals, basic radar principles and servo systems, use of Air Force technical orders, safety and security regulations, maintenance and inspection forms, principles of navigation and fire control, and introduction to the avionics system career field.

2. The second phase includes functional analysis of systems, system integration, operational checkout procedures, use of organizational maintenance test equipment, malfunction isolation, and removal and replacement of line replaceable units, as well as flight-line safety, troubleshooting and repair of aircraft wiring and connectors, and use of technical orders and checklists throughout the course.* It is to be conducted at five CONUS FTDs, one for each model of the F-111/F-15. The individual FTDs are to develop POIs and course material in accordance with the approved training plan.

Phase I

The new Phase I of basic technical training differs from the earlier "maintenance electronics" in that (1) several topics of applied theory have been added, (2) instruction will no longer be self-paced, and (3) basic electronics theory will be extended.

*USAF Training Plan, Course 3AQR32622A-0/4ABF32632A-(X), approved June 4, 1975.

Evaluation of Phase I. Over one-third of formal training in the original training program and 40 percent in the revised training program are in basic electronics topics because many Air Force personnel believe that troubleshooting any avionics system, even on the flight line, requires mastery of traditional basic electronics. They believe that current maintenance problems stem from the way the fundamentals course was taught (self-paced instruction, with open-book examinations), which allowed men to graduate without demonstrating any real knowledge of the subject, and from the shortness of the course, which permitted only a skimpy treatment of a large range of subjects. Our own examination confirmed that these were, in fact, deficiencies in the way the course was taught, although self-pacing was not the primary problem. Any teaching method would be subverted by open-book testing designed to pass as many students as possible rather than evaluate mastery of subject material. Our analysis, however, leads us to believe that the lack of basic electronics skills among first-term airmen does not adversely alter the effectiveness of flight-line maintenance. Our conclusions are based upon several facts:

1. In none of the jobs or tasks observed in the job content survey did maintenance technicians use any skills normally associated with basic electronics.

2. The expert evaluators of the job content summaries confirmed that basic electronics skills were not used. They also indicated that few of the basic electronics topics currently taught in technical school were needed either on the job or as a base for future instruction.

3. The list of basic electronics topics taught in technical school was also reviewed by a senior General Dynamics Technical Representative assigned to flight-line duty at Cannon AFB. He felt that a majority of topics were not relevant to the job. On a topic by topic basis, he indicated that needed material could be covered in 2.3 weeks, compared with 5.4 weeks in the old Lowry AFB course and 6.3 weeks in the new Lowry AFB Phase I course. Several of the new, applied theory topics he thought should be of value.

4. A review of the General Dynamics FIVP data showed that "no known maintenance action justifies use of breakout boxes" and thus an oscilloscope, thereby largely precluding the application of basic electronics to the flight line.

5. The majority of respondents to the TAC questionnaire argued that, "in this job we do not use basic electronics." To put it more strongly, and in the words of one technician at Cannon AFB,

> Actually, it [electronics fundamentals] was a waste--not that the training itself is at fault, but rather the career field. Electronics is not utilized. [We] went too deeply into wiring diagrams, etc., for doing this job. Somebody evidently is still pretending that the 326X2A career field involves electronics, and it doesn't. No more so than turning on a light switch would involve working on a generator.

6. The conclusion that basic electronics is not used on the job is supported by the findings of an independent review by a member of Rand's engineering staff of the flight-line job, technical orders, and training material.*

*See Richard E. Duren, A Proposed Course for Avionics Technicians, R-2049-AF, The Rand Corporation.

The press for more basic electronics training came primarily from senior personnel who were mainly transfers from other career fields. Apparently, they were heavily influenced by their own past training and experience on other, less advanced avionics systems. The desire to expand basic electronics was far from universal, however. For example, one technical sergeant assigned to the F-15 test squadron at Edwards AFB noted that "career electronics technicians who are involuntarily retrained into this AFSC (32672C) are grossly overmatched to the requirements of this job."* Another claimed that after being assigned from a 32570A "they had to detrain me to work in this career field."**

Traditionally, electronics has been highly regarded as a difficult career field. The advent of LRUs and automatic test stations has tended to debase the glamour of the advanced avionics career fields. One way to fight the realities of flight-line maintenance on an integrated digital system is to continue to insist upon a rigorous course in basic electronics, whether it is needed or not. For example, one 7-level technical sergeant from the Bomb/Nav shop at Cannon AFB argued that new airmen were "not adequately instructed in the fundamentals of electronics." However, he also noted that, "a trained monkey could perform this function.... If he is unlucky enough to be assigned to the 326X2 area he will get little or no chance to apply his native intelligence. At least the 326X1 [intermediate avionics maintenance shop] gets to use more electronics

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*For example, the current Bomb/Nav 3-level training is 18 weeks long. The average 7-level had a 40-week basic course when he entered the Air Force, a large portion of which dealt with basic electronics.

**The above and subsequent quotations in this section are from the TAC Supervisory Questionnaire.

in their maintenance." In another case, a senior Bomb/Nav shop supervisor noted on the TAC questionnaire that the Air Force should "teach the new people that are coming into this field the basic electronics that is required for the most part in all electronics fields. The basic knowledge that was taught twenty years ago and is still valid." In a subsequent interview, the supervisor was unable to indicate specific instances when knowledge of basic electronics theory was applied. In essence, his response was, "How can these people be considered electronic technicians if they don't know any electronics?" By contrast, another supervisor at Mountain Home AFB argued that "People naturally resist change. That's the problem with the 326XXX career field now. The test-station-repaired LRU concept is maintenance of the future. The quicker everyone works towards this goal the better."

The desire for rigorous training in basic electronics for status or other nonjob-related reasons was also given in the responses of two supervisors from the 474th Tactical Fighter Wing. One argued that "Graduates are not able to pass a basic electronics course. They will be handicapped during their promotion testing." The other wanted "more basic electronics if it is going to be kept in the SKT testing." This certainly puts the cart before the horse. Insisting on a rigorous course in basic electronics or an impressive AFM 39-1 job description will not change the realities of the job. In fact, it builds false expectations.

<u>Phase II</u>

The Phase II concept and the use of the FTD as an alternative to

the present centralized technical school training have several advantages and disadvantages. Because of their proximity to the flight line, FTDs are better able to maintain relevant course content. It is easier for instructors to visit the work centers to observe the latest techniques in job performance and to find out what shop supervisors need in terms of special training for their personnel. A particularly important plus for the FTD is that the instructors are often drawn from personnel who have had considerable experience in the operating unit and with the equipment that the FTD supports. Thus, they are more likely to know which sections of the technical orders to stress, to know from experience how to fill in where the technical orders are deficient, and in general to draw from working expertise in their teaching.

Finally, in the F-111 program the bench trainers at the FTDs are more realistic than those at technical school. Moreover, trainer downtime because of spare part shortages can be less of a problem for the FTD than it is for the technical school because the operating unit may make spares available or allow FTD instructors to conduct training on equipment from the operating inventory.

FTDs encounter some management problems, primarily in inefficient use of training resources and scheduling difficulties. Because they are so scattered, student loads at FTDs are typically lower than at technical school and economies of scale are hard to achieve. For example, in the period from September 1, 1973, through May 31, 1974, avionics instructors in Cannon's FTD 7-level avionics course averaged 39 percent of the hours an ATC instructor is normally expected to

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spend in the classroom; comparable instructors at Mountain Home AFB averaged somewhat more--50 percent.*

Replacing technical school with FTD training is most efficient if the student is trained at his duty base. The inability to predict the base of ultimate assignment caused some 32632C students to be trained at an FTD on a particular set of equipment and then to be assigned to a different base, thus negating some of the benefits of FTD training. Moreover, in the case of 32632C training students first attended resident technical school at Keesler AFB (Phase I) and often experienced delays between the end of the Keesler course and the start of the FTD course (Phase II). There were frequent comments in the TAC questionnaire about the advantages of moving the Keesler course to the FTD, which would eliminate one move, *i.e.*, combine both phases at the FTD.

Current experience with FTD training, both the 3-level extension of technical school for 32632C and the 7-level orientation training, is mixed. Despite its proximity to the Avionics Maintenance Squadron and the flight line, the FTD can also have problems of separation from the job. For example, although the bench trainers available in the FTDs comprise equipment used in the associated unit, the bench trainer often does not duplicate important features of the operating equipment, such as the location of various LRUs on the aircraft. Separation of equipment into different bench trainers (e.g., the TFR trainer is separated from the INS/DCC/ARS complex in Plattsburg's FTD) further heightens the unreality of the trainers and is especially undesirable for teaching integrated avionics systems. Avionics

*Derived from figures provided by Cannon and Mountain Home FTDs.

personnel need to learn how the systems assigned to other shops will affect their own systems in various modes, as well as how their own systems are interrelated.

FTD instructors and students rarely have access to actual aircraft and never use real malfunctions as opportunities for training. Although the use of bench trainers on which malfunctions can be simulated is a more efficient training technique, opportunities to work on actual aircraft early in training do help to motivate the trainee. A more serious problem, however, is that it is difficult for FTD instructors to avoid becoming isolated from the real-world job situation. It is usual, for example, for an FTD instructor to have been in his present duty for several years and to have lost direct contact with the day-to-day job. The physical demands of FTD duty, like those of technical school, are considerably less than those of the flight line, and opportunities for self-direction are greater. This makes FTD duty quite attractive and encourages a person, once assigned to FTD, to want to remain there. FTD instructors are often viewed with a mixture of envy and scorn by those left behind on the job, and it takes an aggressive and hard-working person who is willing to put in extra hours to maintain his practical expertise. It is easier for him to continue to teach the same things he taught in the past and to put more and more emphasis on the theoretical aspects of the course, which are both more accessible to him and more interesting intellectually. Thus, the quality of training offered in an individual FTD course is highly dependent on the initiative and inclinations of the instructor. It is not surprising, then, for one FTD course to be strongly supported by the user while another is condemned as irrelevant.

Phase II Training at Nellis and Plattsburg FTDs. In September and October 1975, we visited the wings and FTDs at Nellis (F-111A) and Plattsburg (FB-111A) Air Force Bases to learn how Phase II instruction will be carried out (as of early 1976 no students had entered Phase II). The Phase II course at both Nellis and Plattsburg AFBs closely adheres to the structure of the approved ATC training plan in terms of topics, sequence, and the amount of time devoted to specific units of instruction. This means that, as in the basic Lowry AFB Bomb/Nav course, components of the integrated system will be taught separately, one after another, with "systems integration" as a final topic. In spite of its location on the operating bases, no instruction will be given in cockpit familiarization or the removal and installation of LRUs. FTD personnel at both bases told us that the new Phase II courses would be drawn from the 7-level familiarization course.

Based upon our visits to Nellis and Plattsburg AFBs, we conclude that the FTDs have not taken full advantage of their on-base location to ensure the relevance of Phase II instruction. We were told by both AMS and FTD personnel at the bases that there had been no input from the wing to the design of the course, although it would be most helpful. Moreover, aircraft from the operating inventory will not be made available to augment training even though local bench trainers fail to simulate many important interactions of the integrated avionics system.

Analysis of the Nellis and Plattsburg POIs reveals a difference in emphasis on job performance. At Plattsburg AFB, 96 percent of the instruction emphasizes training objectives whose mastery will be tested on the bench trainer. This compares with 64 percent at Nellis

AFB. Analysis of circuit schematics is included at Nellis but not at Plattsburg. In sum, we are left with the impression that Phase II training at Nellis AFB will be somewhat less job relevant than it will be at Plattsburg AFB.

Evaluation of Phase II. The advent of Phase II instruction at the local FTD presents a great opportunity to develop job-relevant training. The foregoing discussion illustrates, however, that the job relevance of the training the FTDs will provide is variable. Even the different Plans of Instruction, which certainly cannot reflect the subtleties of variations in the job proficiency of the instructors, demonstrate this variability.

The new 32632A training program still suffers from many deficiencies of the old technical school course. Not only has basic electronics been unnecessarily expanded, but the shift of set school to the FTDs has not ensured job relevance. In fact, the new curricula for the Phase II courses have been derived from old courses and existing training equipment without a job content analysis and, in most cases, without active participation in the details of course design by experts in job performance. Only the latter kinds of procedures can assure that what should be taught is taught and what should not be taught is not, and that training is both effective and ef[illegible]nt.

[illegible] iming of training still suffers from the "fundies first, sets second" philosophy. Early experience on the job can motivate the individual, give him a general understanding of the operating modes of the avionics system, and help him understand the relevance of more abstract topics. In particular, an individual should not be trained

in troubleshooting before he has ever removed or installed an LRU from the aircraft or run an operational check in the cockpit. Many flight-line personnel have expressed a desire for a better working knowledge of system operation before being trained in troubleshooting.

Finally, although the move of set school to the FTDs has undoubtedly alleviated major problems associated with the Lowry AFB training equipment and instructors, there are still deficiencies in training equipment at the FTDs. Moreover, except for the Phase II course at Cannon, which is discussed below, trainees will continue to have to wait for the award of their 3-level before they have realistic experience on operating aircraft. Variability of job profi iency of FTD instructors will continue to result in variability in the relevance of the training they provide. An effective mechanism for linking training to the job is needed to make sure of the relevance and efficiency of training.

THE TASK ORIENTED TRAINING PROGRAM

As an alternative to the traditional technical school/FTD training, TAC initiated the Task Oriented Training program. TOT directly addresses the content, timing, and location of training. While not directed at entry-level technical training, it has major implications for the conduct of Phase II training at the FTDs. The objective of the TOT program was to provide more effective practical training to TAC maintenance personnel. TAC couched this goal in terms of "improvement of the FTD/OJT interface":

> In order to enhance the quality of TAC's maintenance training and insure its efficiency, TAC and ATC are

> implementing a training program by which FTD training will complement the practical channel of OJT by providing task or job oriented training. Task oriented training will teach a man the knowledge and skills necessary to perform specific tasks that are required in his current job assignment. This program will produce more capable graduates in a shorter amount of time who are able to perform the duties required by their supervisors. This will reduce the training burden on supervisors and complement the qualification requirements of the OJT practical channel.*

In fact, the implementation plan stated that "task oriented courses are designed to replace existing courses in each respective AFSC."**

TOT requires close interaction between wing personnel and the local FTD. For example, a Plan of Instruction is written jointly by Maintenance Training Management and FTD personnel and submitted to Hq ATC in draft form for review and approval.*** Courses are also conducted as a joint ATC/TAC effort. FTD personnel conduct all academic training and some practical training, if so specified in the POI. Academic training on a specific task precedes practical training. The FTD instructor may be assisted in the practical phases of instruction by a TAC Instructor Augmentee, a job-qualified person assigned to the TOT course by the wing's Deputy Commander for Maintenance. The TAC Augmentee conducts whatever practical training the FTD cannot conduct and signs off maintenance actions taken on operational equipment, if sign-off is required and the FTD instructor is not qualified to do so. The POI identifies these requirements, in addition to requirements for the presence of a TAC technician for specific tasks, such as

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*Headquarters TAC, Implementation Plan, Task Oriented Training Program: Tac-Wide, March 1975, p. 1.

**Implementation Plan, p. 4.

***Much of the following discussion was drawn from Hq TAC, Proposed Regulation, TAC 50-XX XX, May 1975 (unpaged).

in-process inspections. Final certification of the student's job proficiency remains the responsibility of shop management personnel.

Maintenance Training Management is responsible for managing the Task Oriented Training program and coordinating with other agencies as needed. An individual in the Management section monitors all TOT courses and schedules courses, resources, and students. Maintenance Training Management also develops a flow chart for local course management that shows the sequence in which each portion of a course will be taught, identifies requirements for equipment, and sets forth the utilization of FTD and TAC instructors.

Responsibility for determination of the training needed by specific individuals remains with shop supervisors. They identify personnel who require FTD training to Maintenance Training Management and determine when an individual should return to FTD for advanced training. "It is the intent of this program that entry level graduates attend the advanced course five to eight months after graduation."*

The most significant feature of the TOT program is that TAC commits its own aircraft, equipment, and personnel to be used for hands-on training and that these commitments are included in formal course documentation. This commitment requires the MAJCOMs to "devise scheduling procedures to incorporate training course, aircraft, equipment and personnel requirements into monthly and weekly published utilization schedules."** "It is incumbent upon wing commanders and

*Implementation Plan, p. 6.

**Headquarters TAC, ATC/TAC Task Oriented Training Report, February 1975, p. 4.

Deputy Commanders for Maintenance to ensure that aircraft and equipment are provided when required to meet training needs."* This is a major step toward breaking the barriers between training and using organizations.

The TOT program did not originally include the 326 career field. In July 1973, teams were established at Luke and Davis Monthan AFBs to test the application of TOT to the aircraft maintenance (431X1C) and egress specialties. "Test evaluations indicated that many benefits could be achieved by employing ... [TOT] procedures," according to the implementation plan.** TAC and ATC then agreed to work jointly to apply the TOT concept to FTD courses in the aircraft maintenance, engine (432X0), and pneudraulics (421X1) specialties. Four prime sites were selected on July 6, 1974: Little Rock, Davis Monthan, Cannon, and Seymour Johnson AFBs.

Both entry-level and advanced FTD courses were developed. The entry-level course was for personnel with no previous experience on the weapon system, which differs from the usual situation in which the FTD offers only a single advanced course that is sometimes given to both experienced and inexperienced personnel. Some courses designed for a given level were broken down still further so that training could be tailored to the specific needs of the individual and the using organization. This approach recognized the often specialized nature of assignments within shops. We illustrate such a modularized approach to course design when we discuss Task Oriented Training in the 326X2A career field developed at Cannon AFB.

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*Proposed Regulation.

**Implementation Plan, p. 2.

Late in 1974, a number of evaluations were made of the TOT courses that had been implemented. One evaluation, conducted by Quality Control personnel, was of the ability of TOT graduates to perform specific tasks. (Similar evaluations of shop personnel are routinely conducted by trained evaluators under the Maintenance Standardization and Evaluation Program (MSEP).) No discrepancies in task performance were noted for 35 3-level graduates at Seymour Johnson AFB. "It is significant to note that graduates of former FTD courses, which were not 'task oriented,' were not capable of being immediately administered MSEP evaluations due to the fact that they were taught system orientation versus task orientation."*

A questionnaire was administered to about 12 Cannon AFB supervisors of 39 graduates of the aircraft maintenance and pneudraulics courses. The results appear below.

KNOWLEDGE AND PROFICIENCY OF TOT GRADUATES COMPARED WITH FTD GRADUATES, AS RATED BY SUPERVISORS

(Percent)

	TOT Greater	TOT Same	TOT Less
Job knowledge	74	26	0
Job proficiency	77	23	0

*Minutes of January 21-23, 1975, Task Oriented Training Conference, p. 1.

In addition, 200 graduates of several courses at Cannon AFB were asked to rate their training. Their responses are summarized below.

HOW TOT GRADUATES RATE COURSE CHARACTERISTICS

(Percent of graduates)

Course Characteristic	Excellent	Good	Unsatisfactory
Subject matter	70	30	0
Training aids	70	20	10
Training method	75	25	0
Learning environment	70	25	5

An interesting fallout of the TOT program at Little Rock AFB was noted in the minutes of a January 1975 TOT conference. In the process of developing the courses, approximately 100 AFTO 22 forms were submitted. It appears that involving field personnel in the preparation of training materials resulted in improvements in the technical orders themselves.

The TOT Course in the 326X2A Field at Cannon Air Force Base

Although the original TOT plan did not include avionics specialties, the wing commander at Cannon AFB asked Hq TAC to include Cannon's 326X2A specialty in the TOT schedule. In mid 1974, Maintenance Training Management personnel, using specialists assigned from Avionics Maintenance Squadron, undertook an intensive effort to design a task-oriented course for 32652A. Their preliminary plan, illustrated in Fig. 4, took the imminent move of the Lowry AFB set

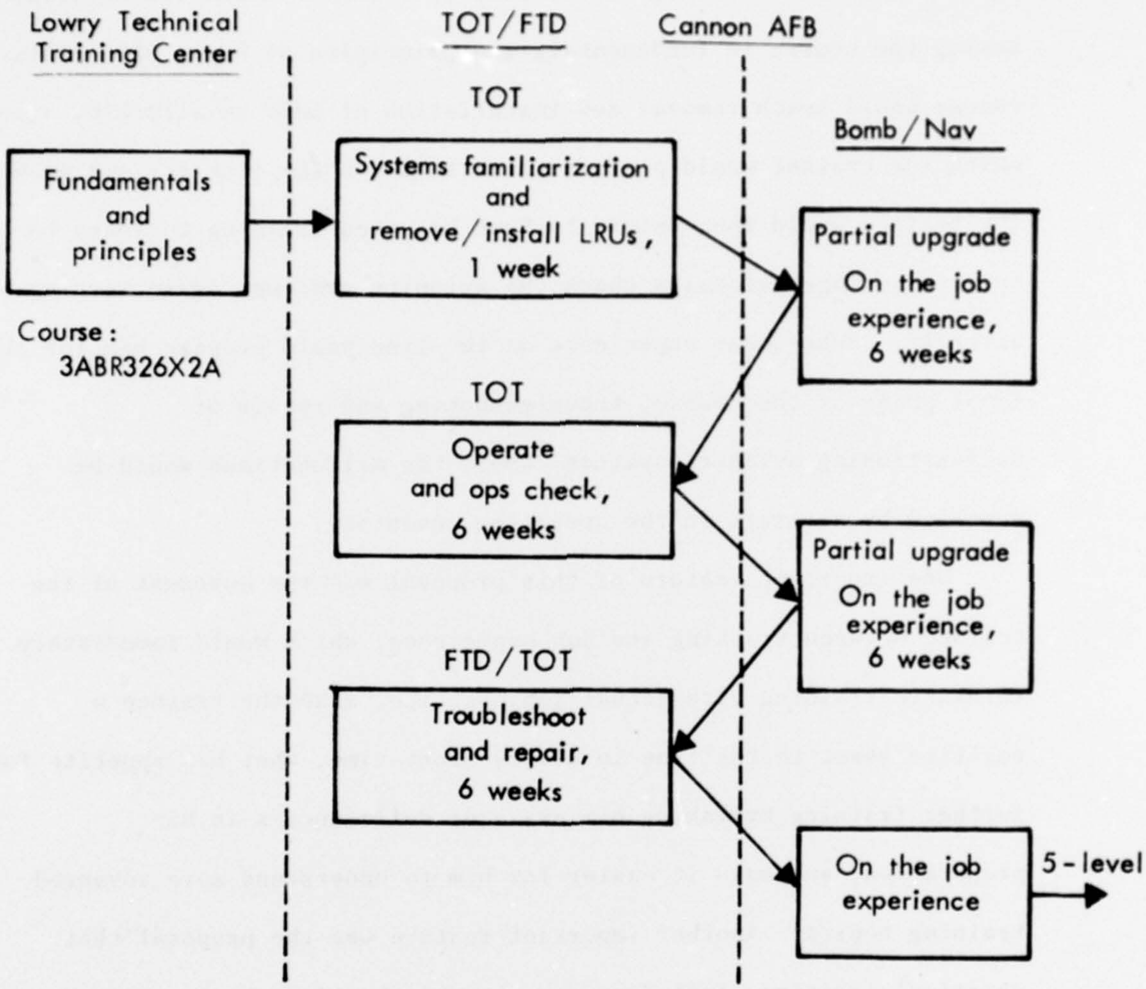

Fig. 4 — Cannon Air Force Base Bomb/Nav training sequence proposed by Maintenance Training Management, Fall 1974

school to the FTDs as a point of departure. They proposed that instead of the traditional set school portion of 3-level technical school, students be assigned directly to a one-week TOT course after taking the course in fundamentals and principles at Lowry AFB. This course would teach removal and installation of LRUs on aircraft, after which the trainee would perform these tasks on the line for six weeks. The trainee would then return to Task Oriented Training to learn to operate and operationally check the avionics systems, again working on aircraft. Subsequent experience on the line would prepare him for the final phase of the course, troubleshooting and repair of malfunctioning avionics systems, where the malfunctions would be supplied by aircraft in the operating inventory.

One important feature of this proposal was the movement of the trainee between training and job experience, which would immediately reinforce training with actual job practice, make the trainee a positive asset to the line in a very short time, whet his appetite for further training by making him aware of deficiencies in his preparation, and make it easier for him to understand more advanced training topics. Another important feature was the proposal that practical training, including some troubleshooting, be carried out on aircraft from the operating inventory. Although this is not always the most efficient use of resources, it certainly is a promising approach for the early stages of training, when orientation and motivation toward the job are being established, and provides a realistic appreciation of troubleshooting problems.

While waiting for Air Training Command's decision on the restructuring of 3-level training, Maintenance Training Management at Cannon AFB implemented in January 1975 a modified and drastically shortened version of their original proposal, as shown in Fig. 5. Graduates at the 3-level from Lowry AFB entered the first phase of TOT to learn to remove/install LRUs on aircraft from the operating inventory. They next were taught to operate and operationally check systems on aircraft before they went to the line. (This segment was reduced from six weeks to two.) They were scheduled to attend the course in troubleshooting and repair after six weeks of experience on the job. Note that the troubleshooting block was reduced from six weeks to about two and one half weeks. Newly arrived 5- and 7-level personnel were also scheduled to take the portions for troubleshooting and/or operating and operationally checking at the discretion of the shop chief.

Between January and May 1975, 26 students completed the five-week course. One TAC instructor did most of the teaching, supported by another TAC individual who assisted in the preparation of course materials and in the practical phases of instruction.

The Cannon TOT courses were given in a hangar dedicated to the program. Two aircraft with maintenance problems (of a type that would not interfere with the instruction during the week) were scheduled into the hangar for a week at a time. Required maintenance was performed outside of scheduled training time through coordination with Job Control.

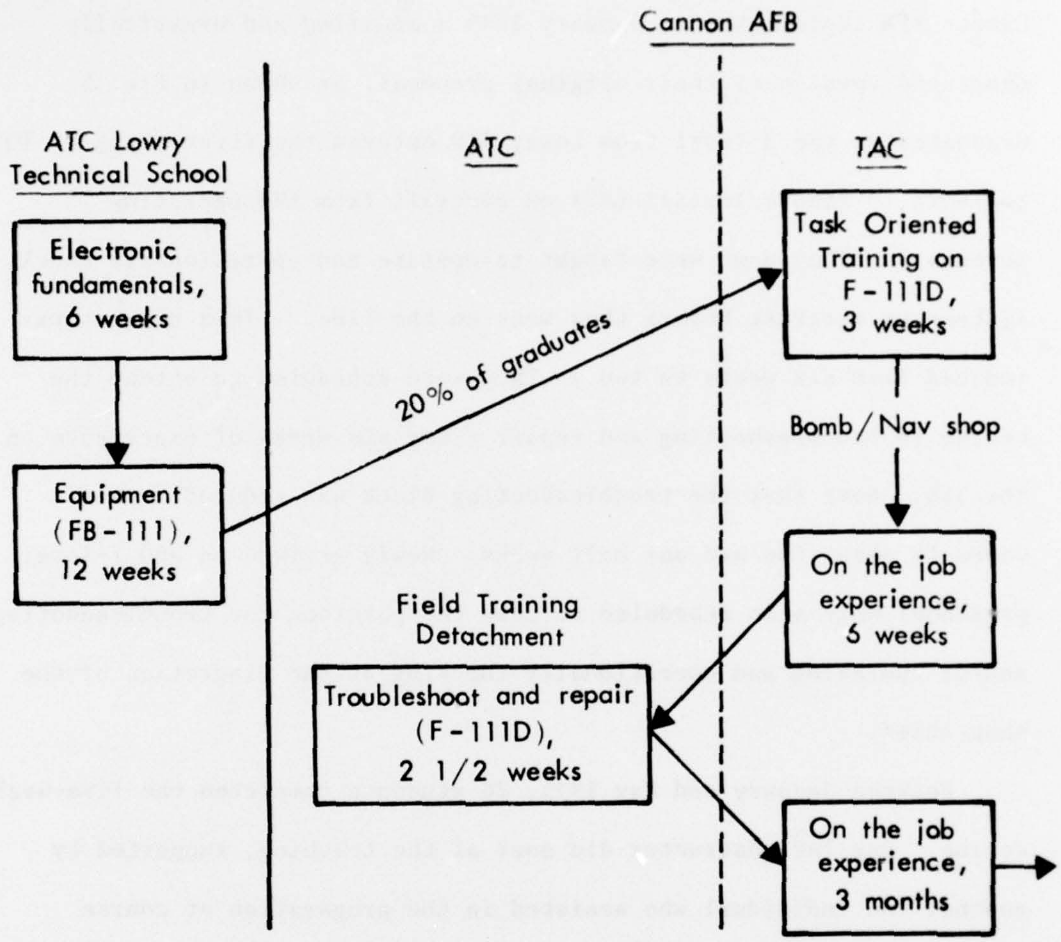

Fig. 5 — Cannon Air Force Base Bomb/Nav maintenance
training implementation, January 1975

The most direct evidence we obtained on the effectiveness of the TOT training in avionics came from discussions with two Bomb/Nav shop supervisors who were familiar with both the TOT graduates and graduates of the FTD course. Both supervisors agreed that the TOT graduates were more knowledgeable about hardware, more aware of aircraft functions and cockpit indicators, and better at performing operational checks. In addition, they could remove/install LRUs without supervision, whereas FTD graduates could not.

Significantly, the supervisors had different expectations of the relative abilities of the TOT and FTD graduates to troubleshoot malfunctions. One felt that both groups would be equally deficient because of inadequate training in basic electronics. The other believed that, even though the old FTD course was "way too long," it produced a better troubleshooter because it went more deeply into the inner circuitry of the LRUs. This disagreement about the content of training desirable for troubleshooting gives further evidence of the inability of some supervisory personnel to identify precisely the knowledge required for troubleshooting advanced avionics.

Unique Features of the TOT Program at Cannon Air Force Base

Although we were not able to visit all of the TOT programs in TAC, we noted differences between their implementation at Cannon AFB and the policy set forth in the original implementation plan, as well as the implementation at some other sites. The most obvious difference was in the relative roles played by Maintenance Training Management and the FTD. At Cannon AFB, Maintenance Training Management played a dominant role. As a result, the hangar and AGE

were dedicated to the program, whereas the official plan merely stated that TOT units would share hangars and AGE as available. At one site, where Maintenance Training Management was relatively weak, difficulties in obtaining aircraft for the pneudraulics course stretched the course length from 76 to 133 hours. At Cannon AFB, students completed the courses on time even when it was difficult to find airframes to support the flying schedule.

Another significant difference was that the implementation plan left the selection of students for the TOT program up to shop management, but at Cannon AFB a Maintenance Training Management representative met with each new person and scheduled training requirements with the person's work section. To complete all training requirements as rapidly as possible, the person's previous training was compared with the needs of the work center, and a personal schedule of required training was constructed.

The implementation plan stated that "ATC will retain full responsibility for managing all media requirements. Existing ATC policies and procedures are adequate to cover media development, standardization and update."* Despite this, the TOT program at Cannon AFB was supported by an in-house capability to develop and produce training media. This is particularly important for training programs that must be highly responsive to local needs.** In addition, Cannon AFB was able to handle special one-of-a-kind courses and low-flow courses by using media to fill in for instructors.

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*Headquarters TAC, ATC/TAC Task Oriented Training Report, February 1975, p. 3.

**Training media include films, sound-on-slide sets, and other nonprinted materials. Media produced through official ATC procedures are expensive and can take over a year to obtain.

Finally, although the implementation plan required that only part of the time of a maintenance officer be set aside for monitoring and managing the TOT program, at Cannon AFB a lieutenant colonel spent full time on the program. He was supported by a full clerk and with four TAC personnel from different AFSCs assigned to temporary duty.

These differences are evidence of the emphasis placed on the TOT program by the Cannon wing commander. As stated in the implementation plan, a key to success of the program is the working relationship between Maintenance Control (Plans and Scheduling and Job Control) and Maintenance Training Command. The head of the TOT program needs sufficient rank to have leverage in his dealings with Maintenance Control, requiring the wing commander to dedicate high-quality resources (particularly people) to support the program.

Seen solely as a substitute for either the traditional FTD or OJT, the Task Oriented Training approach can be both more effective and more efficient in the use of training resources. The TOT effort has a broader message, however: <u>Given strong support of training at the wing level</u>, it is possible to provide training at the base that directly supports job performance. The key is the support of the wing. Without it, training resources, including students, will not be made available.

<u>The Effect of the TOT Program on 32632A Training at Cannon AFB</u>

Originally, Task Oriented Training was seen as a means of improving the OJT/FTD interface. During 1975, the movement of some set school training to the F-111 operating bases presented an opportunity to extend TOT to traditional 3-level training. When we

met with the Cannon FTD personnel, they were in the process of modifying the original technical school course to meet the unique requirements of the Mark II avionics system. Their plan reflected the heavy emphasis on knowledge rather than on task proficiency that was a feature of the former set school course; i.e., the "revised" Specialty Training Standard had only eliminated the effects of representative training.

The TOT personnel, on the other hand, because of the general enthusiasm and the strong support of the wing commander, were optimistic that they would have strong influence on the final version of the Phase II course. They were concerned not only with the course content but with the sequence of training and favored their original plan, shown in Fig. 4.

It soon became evident that organizational and management conflicts would hinder the implementation of the plan. From the ATC side the two major stumbling blocks were (1) the FTD's insistence that 3-level training was ATC's responsibility and that the students, in essence, belonged to ATC until they reached the proficiency specified for each task and knowledge objective listed in the STS, and (2) if the students went to the line before they received the 3-level, ATC would be responsible for whatever they did or was done to them on the line, and would have to pay for any TAC equipment damaged by the students.

On the other side, the Avionics Maintenance Squadron supervisors wanted to control the trainee once he had been assigned to the shop and did not want to be <u>required</u> to send the student back to the FTD where he would be under Air Training Command control. Moreover, if

the student were in the FTD but still assigned to TAC, TAC would be charged with the manpower slot. The upshot was that the concept of moving the trainees between the FTD and the shop was abandoned. As a result, Cannon's Phase II plan resembled the original technical school course more closely than the TOT proposal. The FTD plan called for 12 (rather than five) weeks of training to be allocated to the topics listed in the upper part of Table 21. No training was to take place on aircraft from the operating inventory (FTD bench trainers were to be used), and no training in remove/install LRUs was to be included.*

Cannon AFB TOT personnel worked with the FTD to modify this plan. As a result of their efforts, the course was reduced to 10 weeks and allocated to the topics shown on the bottom part of Table 21. A major change was the inclusion of training in remove/install LRUs on aircraft from the operating inventory. Another change was to precede all training in troubleshooting with training in operation and operational check of all systems. This made sense because the most challenging troubleshooting requires knowledge of the avionics package as an integrated whole and the ability to check all elements of the package. Unfortunately, however, all of the operation and operational check training was to be done on a trainer (not in the cockpit, where much of it is actually carried out). And, even more unfortunately, troubleshooting was to be taught before the trainee had a realistic appreciation of its requirements and complexity.

Finally, as of early 1976, the POI still referenced the original Specialty Training Standard. This means that many training objectives

*USAF Training Plan, Course 3AQR32622A-0/4ABF32632A-(X), approved June 4, 1975.

Table 21

COURSE 4ABF32632A-4

Topic	Hours Per Topic	For Checkout	For Trouble-shooting
a. ATC Proposal			
Orientation and safety	3	--	--
DCC/INS checkout	66	66	--
DCC/INS troubleshooting	27	--	27
IDS checkout	48	48	--
IDS troubleshooting	12	--	12
ARS/DBT checkout	54	54	--
ARS/DBT troubleshooting	18	--	18
TFR checkout	42	42	--
TFR troubleshooting	12	--	12
LARA checkout	8	8	--
LARA troubleshooting	4	--	4
HSD/doppler checkout	18	18	--
HSD/doppler trouble-shooting	6	--	6
Total	359	259	97
b. FTD/TOT Revision			
Orientation and safety	6	--	--
Remove/install LRUs on aircraft	24	--	--
Operation and ops check on trainer			
DCC, CDS,[a] BITE	26	26	--
INS	16	16	--
IDS	30	30	--
IDS & ARS	48	48	--
LARA	14	14	--
TFR	34	34	--
HSD	8	8	--
DRS	9	9	--
DBT	1	1	--
Troubleshoot on trainer			
DCC	36	--	36
INS	9	--	9
IDS	8	--	8
ARS	12	--	12
TFR	14	--	14
LARA	4	--	4
Total	299	186	83

[a] Control and Display Set.

still referred to the purely "knowledge" aspects of the STS, particularly in the "checkout" topics, although the objectives themselves were stated in task-oriented terms.

The 1976 plan for training in the X2A career field at Cannon AFB is illustrated in Fig. 6. Note that the TOT program retained the concept of teaching troubleshooting on aircraft from the operating inventory after the individual obtained job experience. More experienced personnel newly assigned to the base would also attend this course. We do not know what became of the old 7-level FTD course.

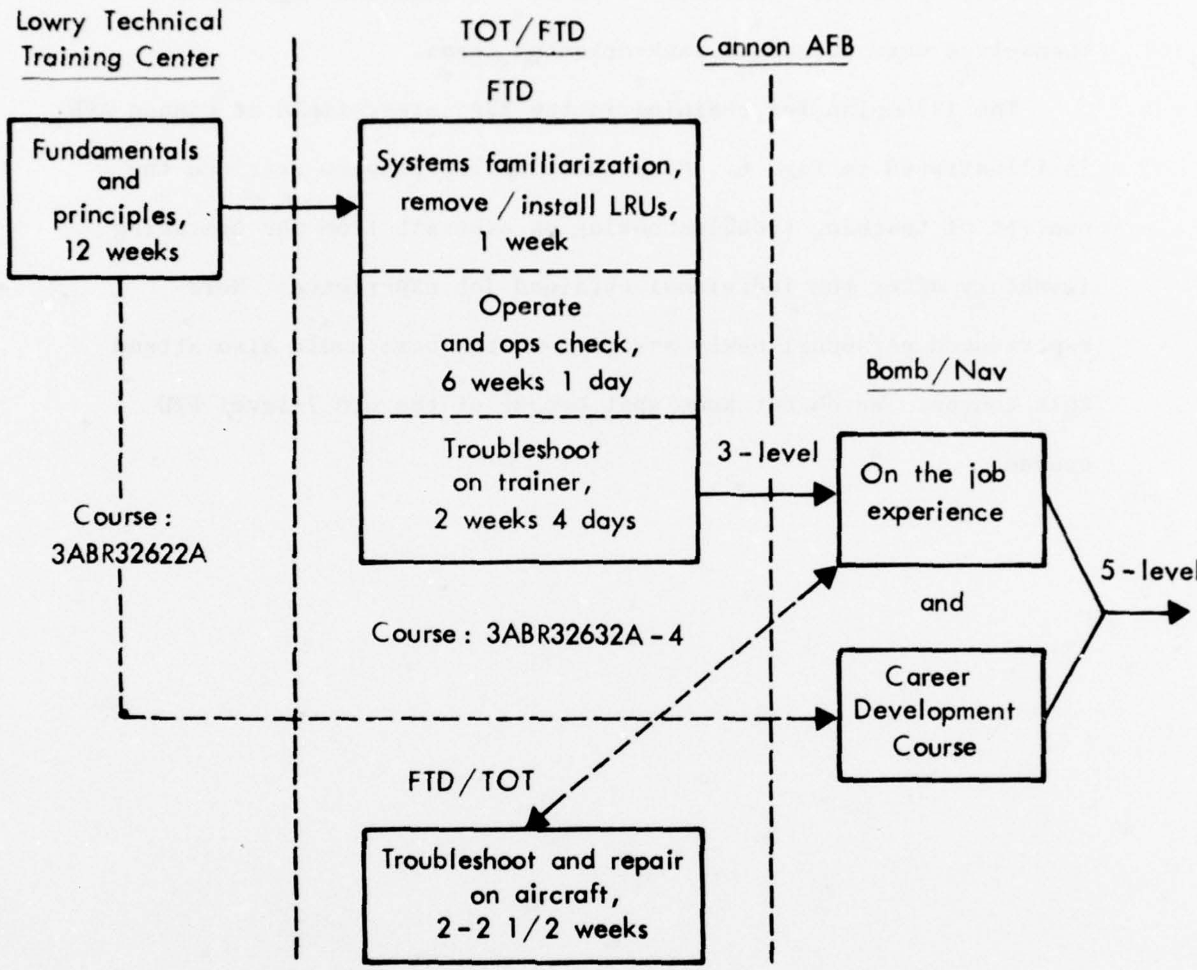

Fig. 6 — Cannon Air Force Base Bomb/Nav training sequence plan, October 1975

V. A RECOMMENDED FORMAL TRAINING PROGRAM FOR FLIGHT-LINE MAINTENANCE

Previous sections of this report have examined the job content of flight-line avionics maintenance in an attempt to clarify training needs. With that as a background, we examined the current training program in detail, highlighting shortcomings and stressing several desirable features, particularly those found in Task Oriented Training. In this section, we describe a blueprint for future avionics training, drawn from the nature of the job, past 326XX training, and previous research on technical training. We discuss five principles for 326 training:

- Job performance should be taught.
- Only job performance should be taught.
- Job performance should be taught formally.
- Job performance should be taught at the operating base and when needed.
- Initial formal training should be alternated with job experience.

JOB PERFORMANCE SHOULD BE TAUGHT

Our job content analysis helped us understand the general types of skills and knowledge needed for job performance in each of the three 326 specialties. Almost all of the skills and knowledge required must be learned because they are not part of the average person's repertoire. In addition, since only a small part of what needs to be learned can be derived from fundamental principles, virtually all

job performance in these specialties is job specific; it cannot be derived by application of general principles. For example, the specialist needs to learn where the LRUs associated with his specialty are located on the aircraft and how to remove and install them properly. Most remove and install actions require only moderate mechanical skill, but some require the use of simple tools or safety wiring. The specialist also needs to learn how to operate the equipment, most of which will be unfamiliar to him, and how to perform operational checks on it. Many operational checks require familiarity with the cockpit and with the location and settings of switches that produce different modes of system operation. Operational checking may require an ability to interpret various displays, and to correctly interpret some of the visual displays requires practice in visual discrimination.

Much of troubleshooting, particularly in the Instrument/Autopilot and Comm/ECM specialties, involves only a single procedure, for example, use of the Built-in Test Equipment. Most of these procedures are described in the technical orders and can be straightforwardly followed to locate the malfunctioning unit, given knowledge of the cockpit and aircraft configurations. Other troubleshooting techniques require additional knowledge to be effective. The use of remove/install as a diagnostic technique is a case in point. Although the technical order often indicates which of several possibly malfunctioning LRUs is the most likely to have caused the problem, other diagnostic tools (including a knowledge of system operation) may sometimes resolve the ambiguity. Strategies for the use of the diagnostic remove/install can include which LRU to switch first or

what other diagnostic tool to use when a spare LRU is not readily available.

The use of the Maintenance Control Unit is another example. The MCU printouts must be read in combination with the original "squawk," indications from the BITE, and computer readouts. In many instances, the sequence of MCU prints must be related to the sequence of tests run through the computer to isolate the faulty LRU. Use of such a complex technique, composed as it is of combinations of logical deduction and pattern recognition, requires both the development of cognitive skill and extensive exposure to patterns of occurrences of clues to LRU failure. It builds on knowledge of the idiosyncrasies of operation of the integrated system as well as on an ability to formulate and apply strategies for use of the diagnostic techniques on that system.

The performance of tasks that are idiosyncratic to specific systems should be taught either on exact copies of the system or on adequate facsimiles for them. Whether a facsimile is adequate depends on what is being taught. For example, a mockup might be sufficient for teaching LRU remove/install, the aircraft itself might be best for operational checking, and a simulator for teaching troubleshooting. For integrated avionics, it is particularly important that all systems that interact on the aircraft interact on the simulator, especially for teaching troubleshooting. A relatively elaborate facsimile may thus be needed for teaching the Bomb/Nav specialty. Facsimiles for Instrument/Autopilot and Comm/ECM can be simpler, but should include cross-specialty interactions if they exist.

ONLY JOB PERFORMANCE SHOULD BE TAUGHT

Traditionally, Air Force entry-level training has been designed to provide a firm base for an airman's progression through various duties he will perform in his specialty over his career and for the various weapon systems assigned to his AFS. Moreover, within the first term, both the Career Development Course and the Specialty Knowledge Test stress knowledge needed for career advancement. But although initial formal technical training is presented as career technical training, in fact only a small percent of personnel in the 326X2 AFS elect to make the Air Force a career. Our analysis of the Uniform Airman Records computer files indicate that on the flight line only 13.9 percent of the technician force stay till their fifth year of service.*

As demonstrated in the preceding section, duties performed by personnel with the 326X2 AFS are generally similar on all weapon systems, although the training required to work on unique systems satisfactorily is often quite dissimilar. In addressing a similar problem,** a USAF Military Personnel Center study group concluded that

> In order to maximize the utility of the first-term work force, qualification and utilization on only one weapons system should be enforced.... This utilization restriction

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*This is the cumulative probability that an airman trained in this AFS will still be in the Air Force four years later. It is calculated from quarterly data from September 1972 through September 1974. The cumulative probability should not be confused with the reenlistment rate, which is reenlistments divided by those eligible to reenlist.

**According to the Palace Claws report, the Chief of Staff requested that consideration be given to restricting the utilization of personnel with F-15 experience to that weapon system alone for a specified period of time. See Classification of Airmen by Weapons Support Systems (Palace Claws), USAF Military Personnel Center, 1975.

> will reduce the amount of training expended on first-term airmen and promote increased expertise within the work force. Equitable assignment policies will dictate requalification in additional weapons systems after the individual enters the career force upon the first reenlistment.*

Although weapon systems training is a necessary condition, it is not in itself sufficient to guarantee that actual job performance will be taught; even though the student might be instructed on the weapon system he will be assigned to work on, training may still be irrelevant to the job he will perform. Nevertheless, weapon system training does represent a major departure from the traditional specialist career-oriented entry-level training.

Training only for first-term jobs has major implications for personnel management and training. Personnel managers would have to identify individuals by weapon system before training and cross-training would be made mandatory between assignments. Rotation between the United States and overseas could result in some "out-of-balance" AFSCs requiring increased training. Training for the first-term job requires not only new utilization policies, i.e., stability in first-term assignments, but also changes in career management. Currently, for promotion an airman advances in grade by first advancing in skill. An important part of skill/grade advancement is completion of the Career Development Course and passage of the Specialty Knowledge Test as part of the Weighted Airman Promotion System. (The SKT is derived from the CDC.) If only job performance is taught, it is clear that the CDC should contain only the material directly pertinent to accomplishment of the first-term

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*Palace Claws, p. 9.

job that is not specifically related to any weapon system.* General principles of radar, navigation, and weapon delivery would be included as would knowledge of the career field, maintenance management, and technical orders. Post-first-term training for the small number of individuals who remain in the Air Force should contain not only those materials necessary for assignment to another weapon system but also that knowledge required for further career advancement within the AFS.

Specific job-oriented training would not only have implications for the management of training and personnel, but would in most cases bring out into the open problems that are currently hidden under the concepts of representative and career training. The above discussion highlights in practical terms the consequence of largely abstract career-oriented training for one important career field. The problem, however, is more general than the maintenance of advanced avionics systems. John Foley recently reviewed the many studies concerning the relative effectiveness of theory and job-oriented training and concluded that

> The results of these studies indicate that the graduates of the job-oriented training programs are able to perform productive work immediately upon assignment to field maintenance units ...
>
> Such results would indicate that much of the theory content ... is not relevant to the performance of the maintenance tasks performed by personnel in their first term. However, the contention that a knowledge of theory is a necessary prerequisite of the successful performance of maintenance is deeply imbedded in the culture of the electronics maintenance community. <u>But there is no doubt</u>

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*An alternative would be to have an evaluation team administer job performance tests to all persons in the AFS being considered for promotion. This would probably be prohibitively expensive.

that this prerequisite adds greatly to the personnel costs of the Air Force*.

JOB PERFORMANCE SHOULD BE TAUGHT FORMALLY

Formal training can be more effective than training on the job because it provides a controlled environment. This greatly increases the probability that training will be provided on all of the important tasks in the job, that each trainee will be taught these tasks, and that he will learn to do the tasks correctly. Formal training can be sequenced to develop skills and knowledge in a systematic way, and students can be assured of sources of information and assistance when they have job-related problems. In addition, students who cannot or will not work as the job requires can be weeded out before they are assigned to a work center.

Assuming that the trainee is adequately motivated to learn, knowledge of such subjects as the vocabulary of the job, the use of technical orders, and general strategies for fault isolation can be taught most effectively in a formal setting. However, the need for

*John P. Foley, Evaluating Maintenance Performance: An Analysis, Air Force Human Resources Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, AD/A-004 761, October 1974, p. 24. Also see W. L. Williams, Jr., and P. G. Whitmore, Jr., The Development and Use of a Performance Test as a Basis for Comparing Technicians With and Without Field Experience. The NIKE AJAX AFC Maintenance Technician, Human Resources Research Office, The George Washington University, Washington, D.C., Technical Report 52, AD-212 663, September 1959; George H. Brown et al., Development and Evaluation of an Improved Field Radio Repair Course, Human Resources Research Office, The George Washington University, Washington, D.C., Technical Report 53, Project Repair, 1959; E. L. Shriver, Determining Training for Electronics System Maintenance: Development and Test of a New Method of Skill and Knowledge Analysis, Human Resources Research Office, The George Washington University, Technical Report 63, Project FORECAST, AD 239 416, Washington, D.C., 1960.

each training objective falling in the "knowledge" category should be established by a rigorous analysis of the requirements for job performance. Much of the knowledge needed is either in the technical orders or should be in them.

Teaching job performance in formal training can produce an airman who is of immediate use to the operating unit. The maintenance supervisor can count on productive work from each man in his shop rather than having to consider a large fraction of his personnel as possible detriments to performance of maintenance. This is particularly important at CONUS bases, which have proportionately large numbers of 3-levels. Personnel thoroughly trained in correct procedures will be less likely to damage equipment during remove/install actions, to pull the wrong LRUs, or to perform mechanical tasks incorrectly. This offers the possibility of alleviating the requirements for spares, reducing the need for cannibalization of equipment, and increasing the Operationally Ready rate of the unit.

Teaching job performance in formal training may not be as expensive as it first may appear. Other Rand work suggests that the hidden cost of OJT is, in fact, considerable. In a pilot study, Gay showed that the OJT cost for airmen in the 431X1 AFSC (Aircraft Maintenance Specialist) was approximately twice the cost of their technical school training and about half the total cost of the Air Force's first-term investment in the airman.*

In addition, graduates of formal training who are proficient in their jobs are likely to have higher morale, and a feeling of

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*Robert M. Gay, Estimating the Cost of On-the-Job Training in Military Occupations: A Methodology and Pilot Study, The Rand Corporation, R-1351-ARPA, April 1974.

achievement is one of the major contributors to job satisfaction.* Job satisfaction may also strongly affect the quality of the work produced. Herzberg et al. found:

> According to the people we interviewed, attitudes toward the job exerted an extremely important influence on the way in which the job was done. In over 60 percent of [the interviews] an improved performance related to improved job attitudes and a decrease in performance related to a change of attitude in a negative direction.**

Thus, there seems to be more than common sense evidence to support the contention that a proficient airman not only saves resources required for OJT but starts work with a better and more productive attitude than the airman who starts his work experience unable to perform the simplest task.

Job performance can be taught in a formal setting. Undergraduate pilot training leads the trainee through a course of study that intersperses classroom instruction with training in simulators and on operational aircraft. Similarly, some commercial airlines train their pilots to fly new aircraft in highly structured courses using combinations of classroom instruction, independent study, and simulators. Finally, civilian corporations, like IBM, train employees to maintain their equipment through structured, in-house programs.

Numerous experiments have been carried out to demonstrate that the maintenance of military equipment can be taught in a formal setting. The Peer Instruction experiment conducted by the Human

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*Frederic Herzberg, Bernard Mausner, and Barbara B. Snyderman, The Motivation to Work, John Wiley & Sons, Inc., New York, 1959.

**The Motivation to Work, p. 87.

Resources Research Organization for the Army in 1968 is probably the most convincing. In this experiment, trainees in the Field Wireman Course (MOS 36K20) were trained by their peers in a course that stressed performance orientation, learning in a job context, and an "absolute criterion" (i.e., each trainee must meet performance standards of speed and accuracy). Graduates of the course were "markedly more competent in terms of job proficiency than were the graduates of the conventional system."*

The 1968 Learner Centered Instruction (LCI) Experiment is particularly relevant because it concerned the maintenance of the avionics system on the F-111A. (The A model is the only F-111 with an analog computer complex.) In this experiment, airmen entering the Weapon Control Systems Mechanic/Technician specialty (AFSC 322X1R) were trained to perform tasks that an analysis had indicated would be essential to the F-111A job. Both at the end of the course and five months after graduation, the experimental students were judged to be better in the speed and accuracy with which they performed tasks <u>under test conditions</u> than their peers who had been trained in the conventional course. These tasks included checkout and detection of malfunctions on a training simulator and a test set, as well as paper-and-pencil troubleshooting. The evaluation report stated that

> This finding in regard to end-of-course results is not particularly surprising, considering the differences in the content of the two courses. The LCI course dealt primarily with teaching the required job behaviors, while the conventional course dealt primarily with teaching electronic

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*Kenneth Weingarten, Jacklyn E. Hungarland, and Mark F. Brennan, <u>Development and Implementation of a Quality-Assured Peer-Instructional Model: Final Report on Work Unit APSTRAT</u>, Human Resources Research Organization, Division No. 3, Presidio of Monterey, California, April 1972, p. v.

> principles of equipment operation. What is of interest is the field follow-up results, which show that the ... LCI subjects maintained their superiority over the Control group.*

Unfortunately, the LCI experimenters themselves rated the performance of both the experimental and control students, making it impossible to accept the experimental evidence without reservation. However, the results were reinforced by the ratings of job performance in the field. Each time a subject in the experiment (LCI or control) worked on the flight line, his supervisor or trainer rated him as he performed the job. At the end of the experiment, the average of the ratings for each subject showed no significant difference between the LCI and control students. This was important because LCI was considerably cheaper (by over 40 percent) than the conventional course, largely because it deleted basic electronics.

Despite the success of the LCI approach in preparing airmen to do the job, it was not implemented. Personnel from the AF Human Resources Research Laboratory, Technical Training Division, attribute this to two causes. Perhaps the more important is that the content of the job changed radically as the F-111A was introduced into operational units, so the training provided by the LCI materials became outdated. Second, graduates of the LCI course lagged in completing their Career Development Course and Specialty Knowledge

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*William J. Pieper, Robert W. Swezey, and Horace H. Valverde, Learner-Centered Instruction (LCI): Volume VII. Evaluation of the LCI Approach, Training Research Division, Air Force Human Resources Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, AFHRL-TR-70-1, February 1970, p. 39.

Test by 5 to 6 months due to their lack of training in basic electronics.

In another experiment in the late 1960s, the DoD and USAF Communications-Electronics Training Service Test Program at Keesler Technical Training Center evaluated alternative training concepts for entry-level training in the Electronic Navigation Equipment specialty and the Aircraft Control and Warning Radar specialty. While these are avionics specialties, men training in these occupations, unlike those in 326AFS, were responsible for both flight-line and shop repair of equipment, including troubleshooting internal circuitry. Moreover, they worked on analog systems, which are much less integrated than the advanced avionics in the F-111, F-15, and F-16 aircraft. Of particular interest were men trained under the "cue-response" concept, which emphasized equipment-oriented training. Electronics principles were introduced only as needed to perform maintenance procedures. Even so, the end-of-course comparison of graduates of the job-oriented and conventional courses favored the former on certain job-oriented maintenance procedures. After 10 weeks on the job, the two groups showed only slight differences in job proficiency.* Yet the experimental group had had only 60 percent as much training as the graduates of the conventional course.

Although we have strong misgivings about the way the evaluation was carried out, we do note that according to the final report** the

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*DoD and USAF Communications-Electronics Training Service Test Program, Synoptic Report for Volumes 1 through 7, Air Training Command, EPR 66-20, May 27, 1968, p. i.

**DoD and USAF Communications-Electronics Training Service Test Program, Synoptic Report, Air Training Command, EPR 66-20, May 28, 1970, pp. 9,10.

cue-response group had "problems when confronted with unfamiliar equipment or unorthodox troubles requiring detailed circuit analysis ... [when] isolating malfunctions below the black box level." Such would not hamper 326 flight-line technicians, since their responsibilities extend only to the sealed LRU (black box). Although "using schematic diagrams and ... knowledge of electronics fundamentals and basic electronics circuits ... are key elements in the theoretical troubleshooting process"* for the Keesler AFB test specialties, the job content survey demonstrated that such knowledge is not used in the 326X2 flight-line occupations.

The comments of the research psychologist assigned to the Keesler project are also illuminating:

> ... at the end of the first year, the supervisory personnel had begun to take a firm stand favoring the men with the more extensive vocabulary and fundamental knowledges, probably because they were needed for the men to complete the requirements for on-the-job training and testing for their "5" skill level AFSC. Apparently the knowledge gap needing to be filled in by the experimental group added a marked burden for the field personnel and their comments reflected this.
>
> If the same on-the-job training and testing requirements [SKT, CDC, etc.] to obtain the "5" skill level are maintained, there is no doubt but that the field training units will have to add to their training programs which they resent and would prefer not to do.
>
> If [this] concept of experimental training should be adopted, ... the first enlistment on-the-job training requirements ... should be reconsidered.*

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*DOD and USAF Communications-Electronics Training Service Test Program, Synoptic Report for Volumes 1 through 7, Air Training Command, EPR 66-20, May 27, 1968. About half of the graduates of the experimental course rated it as inadequate preparation for the CDC/SKT portions of upgrading and promotion, compared to about 7 percent of the graduates of the control courses.

The two experiments described above illustrate the damaging consequences of radically revising a training course without making the necessary concomitant revisions in personnel management, that is, without paying serious attention to the organizational context of training. The Air Force structure reflects a policy that allocates career training (specifically, training in "subject knowledge" and "job knowledge") to formal courses and training in job performance to OJT. This policy is so deeply ingrained in all aspects of training that it is a major barrier to teaching job performance in a formal setting. Thus, the question is not whether job performance can be taught in a formal setting but whether the current military organizational structure can be changed to facilitate formal teaching of job performance. Task Oriented Training, discussed earlier, provides evidence of success in teaching job performance in a formal setting and in an operational environment if the organizational issue is dealt with directly.

JOB PERFORMANCE SHOULD BE TAUGHT FORMALLY AT THE OPERATING BASE AND WHEN NEEDED

Teaching job performance at the operating base improves access to the job itself, which, if taken full advantage of, would significantly improve the relevance of training. For example, instructors and students could work on equipment from the operating inventory, learning equipment locations, removal/installation of LRUs, equipment operation, operational checking, and even some troubleshooting of actual malfunctions.

Instructors would come from the active work force and would be thoroughly familiar with the job. They would visit the work centers

and work in them to learn the latest techniques in job performance, to find out what special training shop supervisors need for their personnel, or to conduct in-shop training sessions. The training center could become a library of information on job performance and could house system-specific mockups, cutaway units, simulators, and bench trainers. Maintenance of training equipment would be readily available for all job incumbents, not only trainees. In short, formal training in job performance at the operating base could benefit both training and the job. The Navy practice of collocating their equivalent of 3-level set school with an aircrew training squadron (the Replacement Air Group) suggests that what we are proposing has proven useful in an operational setting.

A drawback to this proposal is that the base to which the airman will be assigned must be known before training begins. Shortening courses by deleting nonjob-related topics will alleviate this problem somewhat; however, we cannot say at this point whether or how the problem can be completely resolved. Recent changes in training for the Bomb/Nav specialty, discussed previously, suggest that Air Force personnel managers believe they can circumvent the difficulty.

Another possible disadvantage is that moving training to the operating bases will fragment the training to the extent that it becomes too expensive. This does not seem likely, since the FTDs are already providing training to the bulk of the new 3-levels when they arrive on base. Additionally, any increased cost of formal job performance training may be more than offset by decreased length of resident training and the savings in OJT alluded to earlier.

Wherever jobs differ so much from one to another or from one base to another that retraining is needed, such training should be mandatory to assure the proficiency of the work force. A well structured, formal program that relates to and builds on a man's past experience would ensure that before he is assigned to new equipment he is given the opportunity to become thoroughly familiar with it. Specialized advanced training is especially important for senior line supervisors who are responsible for the technical quality of the work in their shop and should be able to supply direction when less experienced personnel are unable to solve a technical problem.

Within the Bomb/Nav specialty, most of the tasks (particularly the more difficult troubleshooting ones) are unique to particular models of aircraft because of the integrated nature of the avionics. Within the Instrument/Autopilot and Comm/ECM specialties, less training will be needed, particularly for reassignments among F-111 models. Retraining needs will obviously be greater for personnel who are assigned to a 326X2X specialty from another career field.

Both the desirability and the feasibility of such an approach are supported by the Navy policy of giving special training in the maintenance of specific equipment, awarding a unique Naval Enlisting Classification code, and assigning on the basis of the special training and code. If a man is assigned to different equipment, he must be given training on that equipment.

The cost of retraining upon reassignment is likely to be small because the training unit would already support initial training. The cost will be smaller still if first-term tours of duty are "stabilized," that is, if the airman is assigned to only one operating base during his first enlistment.

INITIAL FORMAL TRAINING SHOULD BE ALTERNATED WITH JOB EXPERIENCE

Because of the complexity of advanced avionics equipment, alternating periods of formal training with actual job experience would have several advantages. First, the length of the first period of training would be shortened so that the trainee would be able to apply what he has learned while it is still fresh in his mind. The first training period would concentrate on the tasks that are fundamental to the specialty--removal/installation of LRUs, operational checking, and simple troubleshooting. Practice of these skills on the job would give the airman a chance to master them to the extent that they become almost automatic. In addition, during this period the airman would no longer be under the instructor's wing and would have to take responsibility for doing the job correctly, thus motivating the good worker to develop skills of finding information and solving problems. Finally, in the course of his work the airman would become familiar with the concrete context to which the abstract principles of job performance apply. Thus he would be better prepared to appreciate the need for mastery of the aspects of the job that are more intellectually demanding, particularly strategies for troubleshooting and the knowledge of system operation on which they are based. In fact, the trainee may well be primed with questions about job performance when he reenters the classroom.

A further benefit is that the returning trainee will bring to the classroom flight-line experience that could improve the content of the training. Alternating initial formal training with job experience would support the job at the same time that it would reinforce the individual trainee's development of job proficiency.

We are not prepared at this point to say where job experience should be inserted in the initial courses in each of the specialties, how long it should be, or how many parts the entire sequence should contain. Probably an initial period during which the simpler tasks are taught should be followed by at least a month of job performance. The initial training sequence might then be completed with training in the more complex tasks. Such a scheme looks quite feasible for the Bomb/Nav specialty and might also be desirable for the other two.

VI. TRAINING MANAGEMENT

During periods of rapid change it is all too easy for close ties between training and the job to be broken. Although ATC has devised management procedures to make sure that training is responsive to the needs of the field, as illustrated in the preceding section, they are often ineffective. In this section, we will consider problems in the management of training.

Working-level training managers play critical roles in three important areas: first, in the determination of what the job requires in terms of specific knowledge and skills; second, in translating this information into a course that teaches the required knowledge and skills both *effectively and efficiently*; and finally, in making sure that feedback from the field is evaluated to guarantee the relevance of training. These tasks are not only the responsibility of the providers of training; it is equally necessary for the users of trained personnel to make sure that each task is accomplished in accordance with their needs. Unless both sides are actively involved in the process, defects will arise.*

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*The Air Training Command has been aware of the need for improved management of training for a number of years. In the early 1970s, they began applying Instructional Systems Development, a set of systematic procedures for course development and evaluation, on a wide scale within technical training. It has five steps: analysis of the tasks comprising the job; derivation of training requirements from this analysis; specification of training objectives; planning, developing, and internally validating instruction; and evaluation and feedback from the field. The two crucial steps in assuring that the resulting course is relevant to the job are the task analysis and evaluation. Because Instructional Systems Development has been primarily an ATC concern, the tendency has been to concentrate on the planning, development, and internal validation of instruction within the departments and branches of the technical schools.

POLICY FOR THE MANAGEMENT OF FORMAL TRAINING

The starting point for training management is the job description in the Airman Classification Manual, which sets forth in very general terms the knowledge required for the job and duties it entails (see Fig. 7). Next, the Specialty Training Standard expands the job description into training requirements for the specialty. These requirements are stated in terms of prescribed levels of proficiency in subject knowledge, task knowledge, and task performance, which become the training standards for both formal courses and OJT. For formal training, the Specialty Training Standard, in turn, is expanded into a Plan of Instruction, which describes in detail the course that will produce the required levels of proficiency. The list of tasks in the Standard also provides the structure for evaluation and defines the knowledge required for the Career Development Course and the Specialty Knowledge Test. It therefore plays a key role in the promotion process, since the Test in the Weighted Airman Promotion System is generally derived from the Course.* The CDC is a correspondence course in fundamentals and task knowledge common to any job in the specialty. It builds on the material presented in the initial course. Two activities link training directly to the job: the task analysis, which establishes the tasks performed on the job, and evaluation, which rates the effectiveness with which airmen have been trained for the job.

*ATC Regulation 52-2 states, "When a CDC is available, it is used as the sole source for SKT questions" (p. 2).

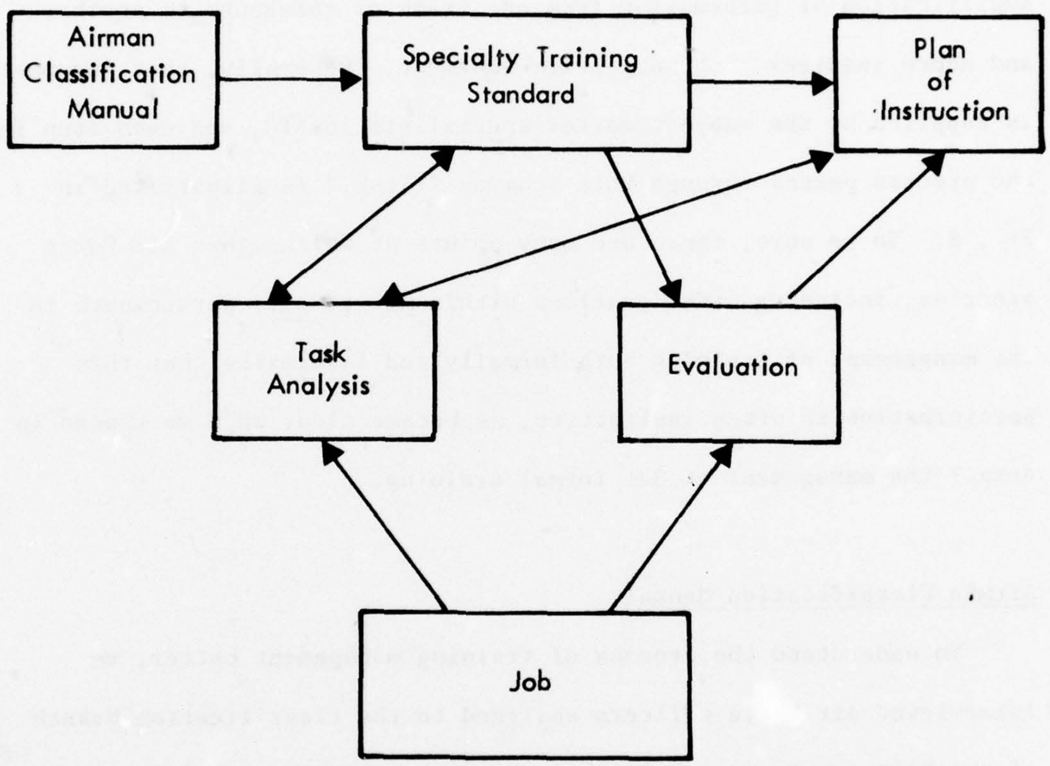

Fig. 7 — Management of formal training: stated policy

MANAGEMENT OF FORMAL TRAINING IN OPERATION

On the face of it, the process we have described is straightforward and contains the links necessary to training relevance. In actuality, however, no step in the process follows directly from another; each is, in effect, a translation or amplification of information from one frame of reference to another and hence requires much subjective judgment. Generally, this judgment is supplied by the subject matter specialists in ATC, and each step in the process passes through this "common filter," as illustrated in Fig. 8. To be sure, there are many points at which other Air Force agencies, including other echelons within ATC itself, participate in the management of training both formally and informally, but this participation is often ineffective, as became clear when we traced in detail the management of 326 formal training.

Airmen Classification Manual

To understand the process of training management better, we interviewed Air Force officers assigned to the classification branch of the Military Personnel Center. We were told that in preparing the job description for the Airmen Classification Manual (AFM 39-1) they rely on inputs from many sources, but for the knowledge required they give heavy weight to ATC's inputs and refer to the course of instruction. As a result, the stated knowledge requirements reflect the current course of instruction rather than the requirements for satisfactory job performance.

Task Analysis

Task analysis is one of the major links between the Specialty

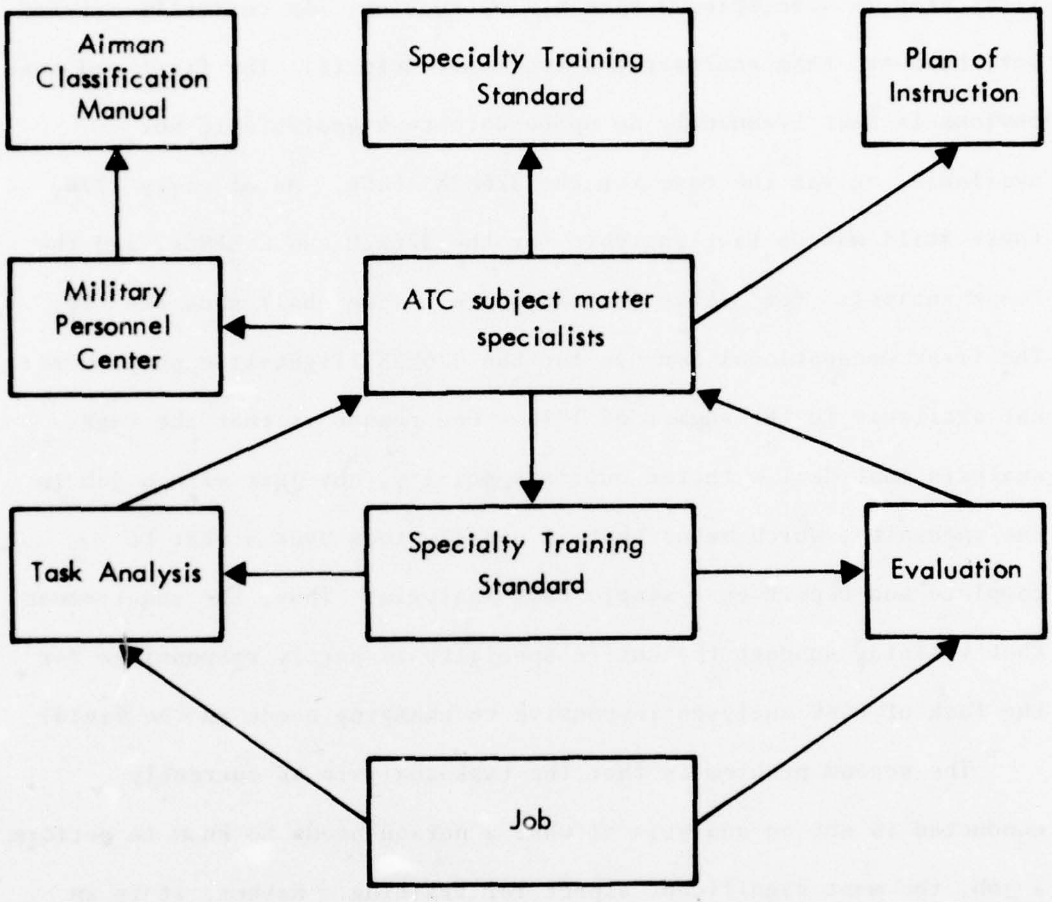

Fig. 8 — Management of formal training: operation

Training Standard, the Plan of Instruction, and the job.* It is generally accepted that a well executed analysis that captures the detailed skills and knowledge required for each task is a desirable first step in developing a Plan of Instruction. As currently carried out, however, task analysis has two major defects. The first and most obvious is that frequently an up-to-date task analysis is not available, as was the case for the 326X2X AFSCs. As of early 1976, there still was no task analysis for the 326X2B and C AFSCs, and the "task analysis" for 326X2A is inadequate, as we shall show shortly. The first Occupational Surveys for the 326X2X flight-line shops were not available in the summer of 1976. One reason is that the task analysis must deal with the entire specialty, not just with a job in the specialty, which means that it usually took over a year to complete and report on a single task analysis. Thus, the requirement that training support the entire specialty is partly responsible for the lack of task analyses responsive to changing needs in the field.

The second problem is that the task analysis as currently conducted is not an analysis of what a person needs to know to perform a job, the most significant aspect for training. Rather, it is an inventory of the tasks performed in the specialty, as defined in an Occupational Survey. The Occupational Surveys, conducted by the Occupational Measurement Branch of ATC, are the preferred source of the task analysis for Instructional Systems Development.** While useful as an indication of the tasks that constitute the specialty,

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*See Air Force Specialty Training Standard, ATC Supplement 1, AFT 8-13, February 1, 1975, p. 4.

**See The Handbook for Designers of Instructional Systems, Vol. II, Task Analysis, AFP 50-58, July 1973.

they provide little guidance on what a person has to know to perform a given task. In general, the information they gather concerns only the percent of people (at various skill levels and with various backgrounds) that perform a given task and the percent of time spent on that task in their current job. For illustration, a page from the inventory for the 326X1A field is shown in Fig. 9. The translation of such an inventory into a training program is not obvious or, in most cases, straightforward. For example, does the task "perform fault isolation procedures on ARS synchronizers" require a knowledge of circuit analysis, Zener diodes, or video amplifiers? Does one need to know how test equipment works, or only how to use the test equipment? To design a training program one must know what knowledge and skills are needed to perform maintenance and make the judgments required on the job.

In a similar vein, ATC's specialist task analysis for the 326X2A career field was not specific enough for determining training requirements. As part of the effort to improve training in this AFSC, ATC asked the F-111 squadrons to respond to a survey questionnaire with the objective of analyzing the specialist tasks. The following discussion of this effort demonstrates that further work is needed to identify the training content for this career field.

The survey at Mountain Home Air Force Base was conducted by members of the Field Training Detachment and the Avionics Maintenance Squadron. In all, 35 members of the AMS at Mountain Home responded. The survey collected data in two areas: task support, which would help identify the importance of the task for training, and training support. Table 22 shows the elements in each category.

JOB INVENTORY (DUTY - TASK LIST)	AFSC 326X1A	PAGE 17 OF 35 PAGES

1. Check tasks you perform now (✓).
2. Add any tasks you do now which are not listed.
3. In the "Time Spent" column, rate checked (✓) tasks on time spent in your present job.

		Check ✓ IF DONE NOW	TIME SPENT Current Job: 1. VERY MUCH BELOW AVERAGE 2. BELOW AVERAGE 3. SLIGHTLY BELOW AVERAGE 4. ABOUT AVERAGE 5. SLIGHTLY ABOVE AVERAGE 6. ABOVE AVERAGE 7. VERY MUCH ABOVE AVERAGE
I. PERFORMING FAULT ISOLATION PROCEDURES ON LINE REPLACEABLE UNITS (LRU)			
1. Perform fault isolation procedures on airspeed electronic amplifiers	61		
2. Perform fault isolation procedures on altitude electronic control amplifiers	62		
3. Perform fault isolation procedures on amplifier power supplies (TFR)	63		
4. Perform fault isolation procedures on analog display indicators	64		
5. Perform fault isolation procedures on antenna receivers	65		
6. Perform fault isolation procedures on antenna selectors	66		
7. Perform fault isolation procedures on ARS antenna assemblies	67		
8. Perform fault isolation procedures on ARS antenna controls	68		
9. Perform fault isolation procedures on ARS antenna pedestals	69		
10. Perform fault isolation procedures on ARS control antenna indicators	70		
* * * * * * * * * * *			
11. Perform fault isolation procedures on ARS indicator recorders	71		
12. Perform fault isolation procedures on ARS synchronizers	72		
13. Perform fault isolation procedures on astro compass trackers	08:73		
14. Perform fault isolation procedures on astro electronic unit analog to digital converters	5		
15. Perform fault isolation procedures on astro electronic unit digital interface assemblies	6		
16. Perform fault isolation procedures on astro electronic unit power supplies	7		
17. Perform fault isolation procedures on attitude director indicators	8		
18. Perform fault isolation procedures on autopilot damper panels	9		
19. Perform fault isolation procedures on ballistics computers	10		
20. Perform fault isolation procedures on battery units	11		
* * * * * * * * * * *			

Fig. 9 — Excerpt from 326X1A job inventory

Table 22

SPECIALIST TASK ANALYSIS OF INTEGRATED AVIONICS SYSTEMS

Task Support

Degree of difficulty	Task requirements
% men performing	Equipment required
Frequency of task	Mission criticality

Training Support

Training required to perform task	Related systems knowledge required
Facilities required	Other related knowledge required

From the point of view of training content, we were especially concerned with the training support category. The task analysis expanded this category into a matrix with tasks as the rows and subject matter and mode of the training required for each task as the columns. This matrix, along with a summary of the Mountain Home AFB data, is shown in Table 23.

The task analysis was too aggregated to permit the selection of training content. A number of the "tasks" are not tasks at all (e.g., modes of operation under INS and DCC are "subject knowledge"). Almost all of the "tasks" are composed of sets of tasks, many of which differ significantly from others in their implications for training. The training focus is also far too general. Does "system theory" mean the theory of how the system works or how it was built, or does it mean

Table 23

MOUNTAIN HOME INTEGRATED AVIONICS SYSTEM SPECIALISTS TASK ANALYSIS:
TRAINING REQUIRED TO PERFORM TASK
(PERCENT FAVORING)

Task	Training					Type Training			
	Electronic Funda-mentals	System Theory	Trouble-shooting	System Integra-tion	Advanced System Theory	Formal	OJT	TTC	FTD
Attack Radar System									
Perform operational checkout	9	80	29	69	6	80	80	0	80
Identify controls/functions	17	100	11	29	6	80	40	0	80
Analyze modes of operations	29	100	29	100	14	86	83	6	80
Perform self test/built-in test	11	91	17	46	0	77	77	0	77
Perform adjustment/alignment	14	77	14	0	0	66	74	0	66
Perform troubleshooting	60	94	94	97	91	100	83	3	97
Remove and replace components	3	3	0	0	0	14	91	0	14
Terrain Following Radar									
Perform operational checkout	6	74	23	91	9	86	91	0	86
Identify functions/controls	6	91	9	34	11	86	34	0	86
Interpret displays	26	100	17	77	17	91	97	6	86
Perform self test/built-in test	9	97	49	100	29	30	30	0	30
Perform adjustment/alignment	9	89	17	29	46	83	74	0	83
Perform troubleshooting	69	100	97	97	89	100	91	0	100
Remove and replace components	0	0	0	0	0	6	94	0	6
INS and DCC									
Operational checkout	9	100	6	31	0	100	89	0	100
Controls/functions	11	97	0	66	0	100	66	0	100
Modes of operations	6	100	0	100	77	100	37	0	100
Self test/built-in test	6	100	97	49	51	100	69	0	100
Data entry procedures	3	100	11	6	23	100	100	0	100
Troubleshoot	49	100	100	51	0	100	100	0	100
Remove and replace	0	0	0	0	0	83	100	0	83
Dual Bombing Timer									
Operational checkout	0	94	0	97	0	86	91	0	86
Interpret displays	0	100	0	0	0	97	17	0	97
Optical Display Sight									
Operational checkout	0	100	14	74	6	86	91	0	86
Controls/functions	0	97	0	86	20	100	91	0	100
Modes of operations	0	100	29	89	51	97	49	0	97
Self test	6	97	20	11	0	57	86	0	57
Troubleshoot	49	100	100	97	51	100	91	0	100
Remove and replace	0	0	0	0	0	29	100	0	29
Systems Integration									
Analyze system integration	83	100	94	100	74	100	100	0	100
Troubleshoot	94	100	100	100	94	100	100	0	100
Electronic Altimeter System									
Operational checkout	29	100	20	100	40	97	80	0	97
Control/functions	0	100	0	0	0	100	9	0	100
Displays	29	100	20	43	0	100	80	0	100
Self test/built-in test	20	94	29	97	0	86	97	0	86
Troubleshooting	57	100	100	100	83	100	91	0	100
Remove and replace	0	0	0	0	0	80	100	0	80

what the system does? Furthermore, how does it differ from "advanced system theory?" In particular, the task analysis indicates that in the seven system areas, it is important to teach troubleshooting in order to perform troubleshooting, which hardly provides insight into how troubleshooting should be taught. Nor does the survey indicate what are necessary electronics fundamentals. In most cases, a majority of the respondents indicated electronics fundamentals were needed for troubleshooting, particularly in systems integration. But what fundamentals--digital systems, oscilloscopes, the theory of electron flow? The Mountain Home AFB survey did include a list of "recommended technical training center subjects," but it did not list the majority of topics taught in the electronics fundamentals course. Thus, TAC's input to this task analysis was undermined by the questions ATC chose to ask.

To some extent, the Air Training Command understands these problems. Of the several ways of gathering job-related information--occupational survey, questionnaire, checklist, individual interview, and observation interview--the Air Force rates the observation interview highest in terms of the specificity, completeness, and accuracy of the information obtained.* Unfortunately, it is generally argued that an adequate task analysis is too expensive to conduct. This seems "penny wise, pound foolish" if the result is an inappropriate course and poorly trained personnel, or personnel trained in irrelevant knowledge or useless skills.

The Electronics Principles Inventory recently developed by ATC's

*AFM 50-2, p. 2-6.

Occupational Measurement Center holds promise for assessing knowledge requirements. Preliminary trials of the Inventory suggested that in some career fields as much as 87 percent of the training in electronics principles was never used on the job.*

The Adequacy of the Specialty Training Standard

The Specialty Training Standard defines not only the tasks to be taught before a 3-level can be awarded, but the level of proficiency required. In addition, it plays major roles in task analysis, training evaluation, and promotion and is often cited by ATC as one of the significant steps in training management where the using commands can have a major impact.**

The STS sets forth standards of knowledge and proficiency in task performance that are to be attained before the airman can be awarded each skill level. But the standards for knowledge and performance are stated in the same terms for all jobs at all skill levels in all specialties. Consequently, these terms are so general that they are ambiguous and only tenuously related to the performance of a particular task. As early as 1969, Hunter et al., in a Human Resources Research Office study for OASD (M&RA), noted that

> The JTS [the former term for the STS] in its present form is ... a document containing "general tasks, knowledges, and proficiency level requirements." It is intermediate between a job description and a listing of learning objectives, and hence serves to obscure rather than delineate a precise relationship between them.

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*Thomas J. O'Connor, A Universal Model for Evaluating Basic Electronics Courses in Terms of Field Utilization of Training, USAF Occupational Measurement Center, Lackland AFB, Texas, 1975, p. 13.

**Air Force Regulation 8-13 sets out procedures by which the using commands review and concur with the STS.

> The Air Force Job Training Standard ... is inadequately derived for the system's needs and insufficiently precise to serve as an ideal set of specifications.*

For example, a common standard for task performance for graduates of an entry-level course is: "Can do most parts of the task. Needs help only on the hardest parts. May not meet local standards for speed and accuracy." With standards such as these, doubtlessly the evaluators of the Lowry AFB course discussed in Sec. IV could state with a clear conscience that

> The training department's analysis of the field questionnaire was that all STS items were being taught to the code level given in the training standard.

Because the STS gives training standards for the entire specialty, it is oriented toward career progression and emphasizes general subject knowledge rather than specific task knowledge required on the job. Thus, it tends to steer the Plan of Instruction away from teaching job performance.

Additionally, since proficiency requirements are so ambiguous, it is not surprising that even this tenuous relationship is sometimes violated by the POI, as was the case in the pre-1975 Bomb/Nav course. The STS required that the 3-level graduate be able to "perform" most parts of the operational checkout of the major systems. Yet the Plan merely required that "given the T.O.s," students be able to "list the

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*Harold G. Hunter et al., The Process of Developing and Improving Course Content for Military Technical Training, Human Resources Research Office, The George Washington University, Washington, D.C., Technical Report 69-9, May 1969 (words in brackets added).

steps in performing the operational checkout." These steps are, of course, listed in the technical orders.

Recall, also, that the STS sets out standards for job proficiency training and the Career Development Course, the two facets of OJT. Supervisors probably use their own judgment in applying the STS as a guide for job proficiency training, but the CDC is another matter. It is prepared by Air Training Command subject matter specialists and is the sole source for the Specialty Knowledge Test, passage of which is required for upgrading. Rather than being derived from an independent analysis of the specialty, however, the Test is likely to be developed after the POI and reflect the course, rather than to provide guidance on how the course should be constructed. For example, in the recent revision of 32632A training a plan was developed without an approved STS. Even more anomalous was the original 326X2A STS, which required knowledge of the FB-111 system because the technical school had FB-111 trainers and the POI referenced the FB-111 system. As noted in the preceding section, knowledge of the FB-111 does not translate into useful job knowledge for a person maintaining advanced avionics on other F-111 models. In fact, to master the Career Development Course, TAC personnel had to review what they had learned about the FB-111 at Lowry AFB, since they had used little of this knowledge on the job. Thus, via the Career Development Course and the Specialty Knowledge Test, the Specialty Training Standard reinforced the content of the Plan of Instruction.

THE PLAN OF INSTRUCTION

It has been seen that for several reasons current procedures

provide inadequate direction for development of the POI, with the result that a large amount of experience and subjective judgment are used in its construction. This process cannot help but reflect both the training environment itself and the predispositions of the subject matter experts. For example, the single line in the STS requiring that a 32632A airman be able to "explain relationship(s) of basic facts and state general principles about ... electronics principles applicable to tasks listed in this STS" was translated into over 40 percent of the formal course. Similarly, we were told by personnel from the Lowry Technical Training Center that since the 326X2A specialty task analysis discussed above was of "poor quality," it was not used in the recent revision of the training plan. The new plans will reflect what has gone before rather than an analysis of the requirements of the job. The Phase II courses at the FTDs will teach the performance of tasks that were in their former 7-level course and that can be carried out on bench trainers already available. The basic electronics course adds or takes away topics rather than selecting the portion of a topic that is applicable to the 32632A job.

It is unfortunate that in the development of the POI, task analysis and the whole concept of Instructional Systems Development have become an end in themselves, instead of means to an end. Instructional Systems Development and task analysis are merely tools that may be useful in providing relevant training. As with any tools, they may be properly or improperly used. The fact that a course has been through Instructional Systems Development or that a task analysis has been performed does not automatically make it a relevant or

effective course. The problem of bywords in training is not new. In 1967 Folley and Elliott wrote:

> People in high places, who presumably would have the authority to improve the quality of training and related activities that so heavily affect maintenance, normally reply, "We're already doing that" when suggestions are made or questions asked. The fact is that a lot of "OK words" are being effectively applied. An incredible discrepancy exists between what the fine sounding labels imply is being done, and the operations that are actually being performed. For example, although "task analysis" and "training objectives" are said to be in use, the central problem of determining valid training content is far from solution.*

Formal Evaluation

Formal evaluation of training is the responsibility of the Evaluation Department in the ATC technical schools. These departments conduct internal and external reviews of both the process and product of training. Internal evaluations primarily ensure that instructors, departments, FTDs, and other agencies within the command are adhering to stated policy. External evaluation ensures that graduates of ATC courses are trained to levels of proficiency as set forth in the Specialty Training Standard. ATC has devised a highly structured and extensive program for formal evaluation.

The fundamental problem with the formal evaluation program is that self-evaluation is rarely candid. For example, the ATC trip report of April 1974 discussed in Sec. IV was highly critical of both the content and conduct of the course given at Lowry AFB and ended with the statement, "Most graduates interviewed considered the Lowry

*John D. Folley, Jr., and Thomas K. Elliott, A Field Survey of Electronic Maintenance Technical Data, Air Force Systems Command, AMRL-TR-67-159, November 1967, p. 25.

course inadequate for doing their job." Despite this candid input, the Training Evaluation Report concluded that

> Internal review of the course did not indicate any training deficiencies other than down time of training equipment.
>
> ...
>
> Personal interviews with graduates and supervisors of graduates seemed to indicate that the graduates were not fully trained on all models of the F-111 aircraft and that additional training was required before the graduates became fully productive. This is a normal condition where the graduates may be assigned to more than one model aircraft.
>
> Recommend that training department (TAV) and Training Plans (TTOX) personnel select additional trainer(s) that, when used with the present trainers, will provide the airman adequate training on the F-111 weapons systems peculiar to his AFSC.

Inputs from the Users of Trained Personnel

The commands receiving graduates of ATC courses make both informal and formal inputs to the management of training. The most revealing recent example was TAC's effort to have the content and conduct of the Lowry AFB course, discussed in Sec. IV, revised by ATC. At the Avionics Superintendent Steering Group Meeting in the spring of 1974 at Lowry AFB, TAC not only expressed their dissatisfaction with representative training but also noted that responses to most of the questionnaires they had administered

> ... indicated that the training received did not adequately prepare them for the tasks they are required to perform in the field.... The most frequent complaint concerned the fact they had received little or no practical training. Although not directly related to the [representative training] concept, the lack of practical training has

> contributed to the overall ineffectiveness of representative training.*

Yet the ASSG report recommended only that "representative training ... be replaced with weapon systems oriented training," and said nothing about teaching job performance. As we have argued, weapon system training is necessary but not sufficient to ensure training in job performance. Thus, TAC did not follow through on this important training input.

A conference was held at Randolph Air Force Base on September 4-6, 1974, to implement ASSG's findings. The minutes of the conference note:

> Basic technical training will be reoriented away from representative, primarily principle-centered instruction towards more specific, primarily weapon systems-centered instruction. Although a thorough Instructional Systems Development (ISD) is required before specifics are known, it can be stated that the general pattern will consist of electronics principles training, a block of training common to a shred as a whole, and finally, "tracking" or "channelizing" the student to the specific weapons systems he will be assigned to on his first tour.**

Despite the lip service to Instructional Systems Development, the Conference, without analysis of actual content of the job or alternative training possibilities, endorsed the two-phase fundamentals general equipment approach to training and added a third phase for teaching specific equipment. As a result, the total length of training remained about the same, basic electronics training was

*Minutes of TAC briefing presented at the Avionics Superintendent Steering Group Meeting, Lowry Air Force Base, May 27-31, 1974.

**Conference minutes on Classification and Training of AFSC 326XX Integrated Avionics (emphasis added).

actually expanded, and practical training remained the responsibility of local units.

Two points at which users of trained personnel make formal input to training management are evaluation, and review and approval of the Specialty Training Standard. To encourage command evaluation of training, ATC has provided all field supervisors with Form 1284, titled "Training Quality Report," on which they may designate areas where course graduates are deficient. However, supervisors are asked to evaluate the graduate against the goals of the STS. Thus, through its control of the STS, ATC sets the goal and then asks to be evaluated against the goal. Moreover, the goals themselves are ambiguous, as noted previously. It is not surprising that practically no Training Quality Reports are submitted from the field. Rather than proving that the commands are satisfied with the ATC product, this indicates the inadequacies of Form 1284 as a mechanism for training evaluation.

Folley and Elliott have argued, and we agree, that the goals "should be reviewed to reflect performance in terms of demonstrated accomplishment, which can be specified in terms of time and errors."* In fact, Maintenance Quality Control at the various operating bases has established standards for speed and accuracy on many tasks.

There are similar problems with command review and approval of the STS outside of ATC. For example, it is unlikely that TAC realized when it approved the Standard that the references to the FB-111 required TAC personnel not only to learn but, after being in the field, to be tested on their knowledge of features unique to a SAC

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*John D. Folley, Jr., and Thomas K. Elliott, A Field Survey of Electronic Maintenance Technical Data, Air Force Systems Command, AMRL-TR-67-159, November 1967, p. 30.

system. After talking to people at TAC, we conclude that TAC's approval of the STS is usually granted without a real effort on TAC's part to understand its content and implications.

SUMMARY

The recent history of the evolution of the Bomb/Nav course illustrates the difficulties of maintaining relevance in training for a rapidly changing job. Training managers and avionics personnel in both ATC and TAC tried to cope with this problem, but their efforts were diluted at two key points--the command evaluation and the task analysis. The lack of success was partly caused by the way each key step in the management process ultimately passes through the same filter--the subject matter experts in Air Training Command.

For a number of years ATC has been aware of the difficulties of devising procedures for the management of training that will ensure its relevance. Considerable time and effort have been devoted to developing and perfecting such techniques as the Occupational Surveys and Instructional Systems Development to try to solve this problem. Yet it remains.

There is a central lesson in ATC's inability to deal with the problem more effectively: ATC, working alone, cannot ensure the relevance of training. The most obvious reason is the tendency of any organization to subvert self-critique. More important is the need for active command involvement in the management of training. Without continuous, open direction and feedback from the users of trained personnel, ATC must fall back on its own subjective perceptions and assessments. In the next section we suggest management procedures for improving the responsiveness of training to command needs.

VII. CONCLUSIONS AND RECOMMENDATIONS

In this section we use conclusions from the foregoing discussion to derive recommendations for improvements in training for flight-line maintenance of advanced avionics and in training management.

CONCLUSIONS

The analysis described in this report focused on a fundamental problem in Air Force technical training: in many instances formal training is not sufficiently relevant to the job. This statement is supported by extensive research in training that goes well beyond our examination of integrated avionics.

The result of irrelevant training is not only that formal training resources are wasted but, more serious, that operational effectiveness may be diminished because airmen do not perform tasks competently. The integrated avionics career field made a unique contribution to the related research mentioned above by highlighting these kinds of inadequacies. Unlike those in most other career fields, many of the more advanced maintenance personnel in integrated avionics lack the knowledge and experience needed to fill gaps in formal training through OJT. The situation was particularly difficult at Cannon AFB where the few people who understood the system carried such a heavy maintenance load that they could not take time to pass their knowledge along to others.

Both ATC and TAC took steps to alleviate these problems. Their efforts shed additional light on the sources of irrelevant

training--Air Force training policies and the management of training within ATC and the MAJCOMs.

Training for Flight-Line Maintenance

To examine the training program, we first established the nature of the job through direct observation of job performance, interviews with job performers, and analysis of the content of about 200 jobs recorded during a two-week period at Cannon AFB. The analysis showed that the most demanding part of the job--fault isolation--requires the informed use of combinations of the external indicators provided by the system; this, in turn, requires that the airman know how the system is integrated, what functions are performed in what boxes, and how a failure in a particular box affects the system. Furthermore, the avionics subsystems on each model of the F-111 are integrated so differently that knowledge of one model does not mean it will be easy to understand another.

In the discussion to follow, we focus on training for the 326X2A career field, where training deficiencies were most obvious. The first-term maintenance force (the bulk of the job performers) had been trained in a course that began with six weeks of basic electronics theory; only one or two weeks of this was related to job performance or even to subsequent instruction in the course. The second part of the course familiarized trainees with each of several avionics subsystems in turn. These subsystems were taken from the FB-111 integrated avionics system, which has some equipment not found on any other model of the F-111 and lacks some equipment that is crucial to other models. Only about 10 percent of the graduates of the course

were destined to work on FB-111s. In general, this part of the course was abstract and only indirectly related to job performance. The inadequacy of this course as preparation for the job was verified through several independent efforts as well as our own.

Training Policy

The use of the FB-111 as a vehicle for training and the emphasis of the course on abstract knowledge were partly consequences of Air Force training policy. Traditionally, initial training has been designed to provide a base for an airman's performance of various duties as he progresses in his specialty and as he works on the various weapon systems assigned to his AFS. Such training has stressed general knowledge related to the career field rather than the specifics of the job. Acquisition of generalized principles is supposed to equip the graduate to transfer what he has learned about a particular system, such as the FB-111, to other systems to which he may be assigned either initially or later in his career. This is presumed to facilitate flexible assignment of personnel among bases and weapon systems. In the case of integrated avionics, however, there was little transfer of learning because of the irrelevance of the general principles taught and the idiosyncratic nature of advanced avionics systems. In addition, only about 14 percent of the technicians were staying in the Air Force until their fifth year of service. Thus, career-oriented training that does not directly support job performance is largely wasted in this career field.

Improving Training Relevance

In an effort to better prepare 326X2A personnel, TAC implemented a very different training approach at Cannon AFB under its Task Oriented Training program. Instructors from the Cannon FTD worked with TAC technicians to design the course and carry out the training, which was given in a hangar using aircraft from the operating inventory. Trainees began by learning to remove and install LRUs, progressed to operation and operational checkout of the avionics subsystems, and ended by doing simple troubleshooting. The course took about three weeks and produced graduates whom supervisors could use immediately.

The Task Oriented Training program made several significant points. It showed that, given strong support by the wing commander, it is possible for the providers of training and the users of trained personnel to work together to resolve problems of training relevance. It also demonstrated that it is possible to teach job performance in formal training, a major recommendation of this study.

There is a considerable body of research that supports our contention that job performance can be taught in formal training. But courses designed in these demonstrations have not been permanently implemented because they have been incompatible with training policy. In addition, even in the face of a serious mismatch between training and the job, it is difficult for ATC to avoid perpetuating existing training content, as is illustrated by ATC's efforts to improve initial training for 326X2A personnel. During 1975, ATC designed and implemented a new course for this career field. It was still in two parts, but only the first was given at the technical school; the second was given at the FTDs at each base that used 326X2A personnel.

The purpose of this change was to orient the systems portion of the training to the particular aircraft to which the graduate would be assigned.

Although this was a step in the right direction, several problems remained. First, the basic electronics portion of the course was actually lengthened; moreover, the physical separation of the two parts of the course reinforced the separation of the theory-oriented portion from job performance. Finally, although the FTD courses were, by and large, more relevant to the job, they were not based on analysis of the job but on the FTD courses that had been given earlier for system familiarization. The result was that they stressed familiarization with particular weapon systems, not necessarily performance of maintenance tasks.

Training Management

The Air Training Command response illustrates a general problem for training management--the difficulty of keeping existing training procedures and resources from dictating course design and course content. In recognition of this difficulty, ATC has devised several processes for linking training to the needs of the field. These links are often ineffective, however, for two reasons. One is that all of them depend for their detailed specification and implementation on the subjective judgment of ATC school personnel, which is naturally colored by the training command environment. The second reason is that the MAJCOMs, in the past, have viewed training as largely ATC's business and have not aggressively pushed their training concerns via the mechanisms that ATC has provided.

RECOMMENDATIONS

The recommendations fall into the areas of training content, location, and timing. The Air Force has already taken action in some of the directions we believe are desirable. The development of training in the 326X2 AFS makes it clear, however, that it is not easy for the training program to keep up with the needs of the field. We believe that improved management procedures are critical. We therefore also recommend changes in procedures for designing and evaluating training programs that, we believe, would improve both the effectiveness and the efficiency of Air Force training in areas which, like advanced avionics, are undergoing rapid technological change.

Training for Flight-Line Maintenance of Advanced Avionics

Content: Teach Job Performance. Formal instruction in performance of flight-line maintenance jobs would make more efficient use of Air Force resources and at the same time would improve job performance. A necessary first step is to determine what job performance requires in terms of skill and knowledge; previous work has shown that it is particularly important to determine how fault isolation is performed for integrated systems.* A member of the Rand engineering staff has investigated this issue in depth for the F-111D and has synthesized an outline of a course whose graduates would be immediately productive on the flight line and would also have the understanding of system integration required for most fault

*Polly Carpenter-Huffman, John Neufer, and Bernard Rostker, Analysis of the Content of Advanced Avionics Maintenance Jobs, R-2017-AF, The Rand Corporation, and Richard E. Duren, A Proposed Course for Avionics Technicians, R-2049-AF, The Rand Corporation.

isolation.* Similar analysis is needed to build training for flight-line maintenance of the other models of the F-111, F-15, and F-16.

Training should concentrate on the development of job performance skills in a reasonable facsimile of a job setting. Particularly for flight-line maintenance of advanced avionics, training on system integration should be carried out on a truly integrated system--that is, either on the aircraft itself or on a reasonable facsimile of it. (A reasonable facsimile is one in which all systems interact that interact on the aircraft.) In some instances, it may be desirable to design new trainers or maintenance simulators that have this feature.

It is crucial that instructors know the job intimately and are adept at teaching job performance. This will require them to perform the job on the flight line at frequent enough intervals to remain current (perhaps as determined by their ability to do the more demanding task or tasks for which procedures have recently been revised) and to learn how to guide trainees through task performance (rather than showing and telling them how it is done).

Only job performance should be taught initially, that is, all of the content of training should support job performance directly, because so few airmen make careers of the 326X2X specialties that generalized/theoretical training intended as a basis for career advancement is largely wasted.

Location: Train for the Job Where the Job Is. Our proposal that the bulk of 326X2 training be strongly oriented to the tasks a

*R-2049-AF.

man will perform on a particular aircraft model and the difficulties of maintaining such an orientation for many diverse aircraft models at a single school remote from operating bases argue for moving the training to the operating bases. The inefficiencies in the use of training resources that will result from such a change are more apparent than real; centralized training is less efficient because much of what is learned there is either forgotten or never used. The screening function provided at technical school could better be done on base, where an airman's willingness and ability to work on the job would be assessed, rather than his survival skills in an academic environment.

To be effective, base-level job-oriented training requires close cooperation between the training and using organizations. Specifically, the training organization must see its primary mission as supporting the user's immediate training needs; the using organization must see training support as of primary importance to its mission. This is especially true at CONUS bases, where a large fraction of the personnel (26 percent on the Cannon AFB flight line in 1974) are 3-levels and where, as a result, the base is being used for training maintenance personnel as well as pilots.

Timing: Training and the Job Should Reinforce One Another. All knowledge or theory required to support task performance should be taught only during the actual job performance instruction. (This is referred to as training "in a functional context."*) Two arguments

*The Human Resources Research Office has developed and demonstrated this concept in a number of programs. See, for example, John E. Taylor, Eugene R. Michaels, and Mark F. Brennan, The Concepts of Performance-Oriented Instructions Used in Developing the Experimental Volunteer Army Program, HumRRO-TR-72-7, March 1972.

support this conclusion. First, training should be coherent so that it is obvious to the trainee how all of what he is learning fits together to improve his skills on the job. Second, teaching the more abstract aspects of job performance only as required during training in job skills helps weed out unnecessary theory. Teaching theory only as part of teaching job performance will require a major overhaul of current training programs but will probably pay for itself in improved training efficiency and effectiveness.

During initial training (not after) the trainee should work on the flight line. (For example, he could go to school in the morning and work in the afternoon.) This would reinforce learning and bring student-oriented insights to the classroom; it would also enhance the relevance of training content to job performance by providing a strong mechanism for communication.

The initial training in the 326X2 AFS should be carried out only on the equipment the man will maintain during his first duty assignment. When and if he is assigned to maintain significantly different equipment, he should be required to be trained on that equipment, regardless of his grade.

In specialties such as the 326X2, where abstract training is initially minimal, a general and thorough course in basic electronics or other relevant theory might be offered as an incentive for reenlistment. Such courses could be given in technical school or at FTD. If the course is given at the FTD, first-termers should be encouraged to study theory in their spare time. Alternatively, or concurrently, a self-study package could be provided to whoever wants it.

Training Management

There are three areas where we believe the management of training can be improved--making Instructional Systems Development more effective in ensuring the relevance of training to the job, improving the consonance between training policy and the particularities of each specialty, and getting the users of trained personnel more effectively involved with training. Unless changes are made in these areas, teaching job performance in avionics maintenance training will be just one more demonstration that is dropped, after an initial flurry of support, when the fundamental countercurrents in the training system slowly engulf it.

Strengthen the Instructional Systems Development Steps Relating Training to Job Performance. Presently, the ISD links between training and the job are inadequate. Usually there is no up-to-date task analysis; if anything is available, it is not an analysis of what a job incumbent needs to know and be able to do but is instead an inventory of the tasks usually performed (an Occupational Survey report). A task analysis should establish not only what is done, but, more important from the standpoint of training, what knowledge is used on the job. The Electronics Principles Inventory demonstrates the feasibility of such an approach. Thus, the Occupational Survey should be expanded into a skill and knowledge analysis.

The last step in Instructional Systems Development is field evaluation, which is crucial not only in testing the effectiveness of current training but in ensuring that training remains relevant. Because of deficiencies endemic to self-evaluation, field evaluation should be the responsibility of an agency external to the school whose

course is being evaluated--preferably external to technical training itself. Along the same lines, criteria for evaluation should be specified by other than course personnel or technical training. They could be drawn from the course objectives themselves, from performance standards established by Quality Control, or from some combination.

Training Policy: Tailor the Amount and Timing of Generalized and Career-Oriented Training to the Needs of Each Specialty. A fundamental source of the deficiencies in training for flight-line maintenance of advanced avionics is ATC's blanket policy that initial training should prepare the airman for career advancement as well as for OJT. Such a policy may be desirable for specialties where the percentage of entering airmen who make the specialty their career is high or where there is an appreciable amount of knowledge that supports most of the jobs in the specialty, that is, is generalizable across the specialty. The 326X2X specialties fit neither of these criteria. Thus, a better blanket policy would be that the phasing of generalized or career-oriented training should be tailored to fit each specialty.

The Users: Make the Users of Trained Personnel More Active Partners in the Training Process. Users of trained personnel quite naturally view their mission as other than training (even though some MAJCOM bases in the CONUS are primarily pilot training bases). Dedication to the mission should be more farsighted than is often the case. For example, it makes no sense to concentrate resources on training pilots to the detriment of keeping their aircraft in flyable condition. Maintenance training should be emphasized as strongly as pilot training. Both at headquarters and at the wing

level, positions of sufficient authority should be established to ensure the support of maintenance training. The Task Oriented Training program at Cannon AFB demonstrates the benefits of strong wing support. This approach should be extended and given the support needed to make it effective.

User participation in the management of training should be strengthened in the two steps of Instructional Systems Development that link training to the job--task analysis and field evaluation. The user should be active in choosing the tasks to be taught and the proficiency expected of the graduate. The vague codes of the Specialty Training Standard should be replaced by criteria specific to each task. To forestall the unsupportable inflation of training requirements that might result, the user should have to pay for the training he requires either in dollars or other resources. Design of effective policies and procedures needs further work.

Similarly, better procedures are needed to involve the user with field evaluation. There is no substitute for nonthreatening face-to-face interviews with graduates and their supervisors. Questionnaires should be simple, in the airman's terms, and also devoid of threat to him. Perhaps they should be processed initially by people in the using command who are responsible for training, rather than by ATC. And, most important, if the evaluation reveals flaws in training, positive remedies must ensue, preferably from user participation in their formulation.

APPENDIX

Table A-1

SUPERVISOR EXPERIENCE AND BACKGROUND
Cannon Air Force Base
Bomb/Nav

Date Assigned	Grade	Percent of Shop Systems			Formal Training 326 AFSC		Other AFSCs [a]	
		Worked Last 6 Mo.	Worked Prior Base	OJT Completed	3-Level	Advanced	3-Level Tng.	Other
11/71	E-5	4	7	100	N	N	322X1R	320X0
3/72	E-7	0	78	100	N	N	303X3, 304X0A	301X4A, 322X1R, 301X4
6/72	E-6	0	0	80	N	9/72	301XX, 301X4	
7/72	E-7	67	0	80	N	9/72	301X0C	301X1
8/72	E-6	52	0	0	N	N	293X1, 322X1F, 322X1R	
5/73	E-6	89	63	0	N	N	301X1	
5/73	E-5	26	19	100	N	10/73	301X1	301X4, 322X1R
7/73	E-5	0	19	10	N	11/73	322X1N	322X1R
3/74	E-5	93	81	100	N	6/74	301X4	
7/74	E-5	41	52	50	N	N	301XX	
9/74	E-5	0	100	40	N	N	321X0K	321X0R
9/74	E-7	0	59	20	N	N	322X0	

[a] 301 AFS has become 328 AFS.

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Table A-2

SUPERVISOR EXPERIENCE AND BACKGROUND
Cannon Air Force Base
Instrument/Autopilot

Date Assigned	Grade	Percent of Shop Systems: Worked Last 6 mo.	Percent of Shop Systems: Worked Prior Base	Percent of Shop Systems: OJT Completed	Formal Training, 326 AFSC: 3-Level	Formal Training, 326 AFSC: Advanced	Other AFSCs [a]: 3-Level Tng.	Other AFSCs [a]: Other
5/71	E-6	97	31	0	N [b]	2/73	323X0	325X0
4/72	E-5	91	0	38	N	N	422X0	325X1,325X0
5/72	E-6	31	62	23	N	N	N	422X0,325X1,325X0
7/72	E-5	88	0	100	N	N	422X0	325X1,325X0
4/74	E-5	88	66	0	N	N	422X0	325X1
9/74	E-6	0	72	U [c]	N	5/72	422X0	325X1
9/74	E-6	22	44	0	7/74	N	544X0Y,325X0A	431X1C
Comm/ECM								
1/72	E-6	81	26	100	N	12/72	301X0C	301X1
4/72	E-5	74	0	100	N	10/72	301X0	
7/72	E-6	39	0	100	N	12/72	328X3	
9/72	E-5	39	0	100	N	1/74	301X0	
4/74	E-5	90	90	31	N	N	301X3	301X0,301X1
5/74	E-6	39	55	100	N	N	301X0	301X1,328X0

[a] 301 AFS now 328 AFS.

[b] N = None.

[c] U = Unknown.

Table A-3

SUPERVISOR EXPERIENCE AND BACKGROUND
Mountain Home Air Force Base
Bomb/Nav

Date Assigned	Grade	Percent of Shop Systems: Worked Last 6 Mo.	Percent of Shop Systems: Worked Prior Base	Percent of Shop Systems: OJT Completed	Formal Training 326 AFSC: 3-Level	Formal Training 326 AFSC: Advanced	Other AFSCs [a]: 3-Level Tng.	Other AFSCs [a]: Other
7/71	E-6	88	0	92	N[b]	N	U[c]	301X4
8/71	E-5	0	42	19	N	N	322X1R	
11/71	E-7	0	73	100	N	6/72	322XXX,322X1R	
12/71	E-5	81	0	0	N	3/72	U	
1/72	E-5	0	0	31	N	8/72	U	322X1R
8/72	E-5	76	0	100	N	11/72	U	
11/73	E-6	0	0	0	5/74	8/74	U	
3/74	E-6	96	88	100	N	4/74	431X1A,322X1R	
6/74	E-5	0	69	4	N	8/74	322X0B	322X1R
6/74	E-6	96	50	0	N	N		
7/74	E-7	92	0	100	N	N	U	301X4

[a] 301 AFS now 328 AFS.

[b] N = None.

[c] U = Unknown.

Table A-4

SUPERVISOR EXPERIENCE AND BACKGROUND
Mountain Home Air Force Base
Instrument/Autopilot

Date Assigned	Grade	Percent of Shop Systems: Worked Last 6 Mo.	Percent of Shop Systems: Worked Prior Base	Percent of Shop Systems: OJT Completed	Formal Training, 326 AFSC: 3-Level	Formal Training, 326 AFSC: Advanced	Other AFSCs[a]: 3-Level Tng.	Other AFSCs[a]: Other
9/71	E-6	100	73	0	N[b]	N	422X0	325X1
6/73	E-5	0	0	0	N	3/72	325X0	
10/73	E-5	76	64	0	N	DNG[c]	325X0	
4/74	E-6	0	100	0	N	4/72	325X0	325X0A
8/74	E-7	0	0	0	7/74	N	U[d]	
9/74	E-6	0	100	0	N	N	422X0	
9/74	E-6	39	0	0	9/74	N	325X0	325X1
Comm/ECM								
7/71	E-6	94	0	100	N	N	301X0	
9/73	E-6	0	100	0	N	N	301X4, 301X3	
10/73	E-6	81	52	32	N	N	534X0, 301X3A	301X4
11/73	E-5	0	0	100	N	N	328X3	
12/73	E-5	100	100	100	N	N	301X3	301X0, 301X1, 328X3
2/74	E-7	48	0	0	N	DNG	301X0	301X1, 328X4
5/74	E-6	97	0	100	N	9/72	303X2	301X3, 305X0, 328X3
6/74	E-5	3	100	10	N	N	303X2	301X1
9/74	E-6	16	100	0	N	N	301X0	328XX

[a] 301 AFS now 328 AFS.

[b] N = None.

[c] DNG = Date Not Given.

[d] U = Unknown.